# PHILOSOPHICAL

# TRANSACTIONS,

OF THE

# ROYAL SOCIETY

OF

# LONDON.

FOR THE YEAR MDCCCXXII.

PART I.

LONDON:

PRINTED BY W. NICOL, SUCCESSOR TO W. BULMER AND CO.
CLEVELAND-ROW, ST. JAMES'S;
AND SOLD BY G. AND W. NICOL, PALL-MALL, PRINTERS TO THE
ROYAL SOCIETY.

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# ADVERTISEMENT.

THE Committee appointed by the *Royal Society* to direct the publication of the *Philosophical Transactions*, take this opportunity to acquaint the Public, that it fully appears, as well from the council-books and journals of the Society, as from repeated declarations which have been made in several former *Transactions*, that the printing of them was always, from time to time, the single act of the respective Secretaries, till the Forty-seventh Volume: the Society, as a Body, never interesting themselves any further in their publication, than by occasionally recommending the revival of them to some of their Secretaries, when, from the particular circumstances of their affairs, the *Transactions* had happened for any length of time to be intermitted. And this seems principally to have been done with a view to satisfy the Public, that their usual meetings were then continued, for the improvement of knowledge, and benefit of mankind, the great ends of their first institution by the Royal Charters, and which they have ever since steadily pursued.

But the Society being of late years greatly enlarged, and their communications more numerous, it was thought advisable that a Committee of their members should be appointed, to reconsider the papers read before them, and select out of them such as they should judge most proper for publication in the future *Transactions*; which was accordingly done upon the 26th of March, 1752. And the grounds of their choice are, and will continue to

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be, the importance and singularity of the subjects, or the advantageous manner of treating them; without pretending to answer for the certainty of the facts, or propriety of the reasonings, contained in the several papers so published, which must still rest on the credit or judgment of their respective authors.

It is likewise necessary on this occasion to remark, that it is an established rule of the Society, to which they will always adhere, never to give their opinion, as a Body, upon any subject, either of Nature or Art, that comes before them. And therefore the thanks, which are frequently proposed from the Chair, to be given to the authors of such papers as are read at their accustomed meetings, or to the persons through whose hands they received them, are to be considered in no other light than as a matter of civility, in return for the respect shown to the Society by those communications. The like also is to be said with regard to the several projects, inventions, and curiosities of various kinds, which are often exhibited to the Society; the authors whereof, or those who exhibit them, frequently take the liberty to report, and even to certify in the public news-papers, that they have met with the highest applause and approbation. And therefore it is hoped, that no regard will hereafter be paid to such reports and public notices; which in some instances have been too lightly credited, to the dishonour of the Society.

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*Meteorological Journal kept at the Apartments of the Royal Society, by Order of the President and Council.*

The PRESIDENT and COUNCIL of the ROYAL SOCIETY adjudged the Medal on Sir GODFREY COPLEY's Donation,

1. To Captain EDWARD SABINE, for his various Communications to the Royal Society relating to his researches made in the late expedition to the Arctic regions.

2. To JOHN FREDERICK WILLIAM HERSCHEL, Esq. for his Papers printed in the Philosophical Transactions.

# PHILOSOPHICAL TRANSACTIONS.

I. *The Bakerian Lecture. An Account of Experiments to determine the amount of the Dip of the Magnetic Needle in London, in August* 1821; *with Remarks on the Instruments which are usually employed in such determinations. By Captain* EDWARD SABINE *of the Royal Regiment of Artillery, F. R. S.*

Read November 22, 1821.

THE increased attention which has been given of late years by several philosophers to the subject of *magnetism*, and the consequent advance which has been made in this branch of natural knowledge, render it desirable, that a greater degree of accuracy should be obtained in all respects, in observing its various terrestrial phenomena, than hitherto.

This remark applies especially to observations on the dip of the needle; the instruments in general use for this purpose have received little or no improvement during the last fifty years, and produce results which can only be considered as approximate, even when the observer has made himself well acquainted with the various sources of inaccuracy in the instrument, and has adopted precautions to guard against, or remedy them.

Many of these, indeed, are not difficult of detection, and admit of compensation by certain known methods of observing; such are those which are caused by incorrect graduation, by the eccentricity of the needle with respect to the divided circle, by the agate planes which support the axis of the needle not being truly horizontal, or by their non-coincidence with the right line joining the zeros of the circle. The errors to which even the most careful determinations are subject, are to be referred chiefly to faults in the construction of the needle itself; 1st, to imperfection in the axis, whereby the needle, on being made to oscillate, will not return with certainty in repeated trials to the same division of the limb; and, 2ndly, to the difficulty which even the most skilful artists experience, in the endeavour to make the axis of motion pass through the centre of gravity; a condition which is essential to accuracy in the usual mode of observation, but of which it may be safely said, that its accomplishment admits of no very certain proof, and that it is rarely or never succeeded in.

It is obvious that a needle, of which the balance is not thus correctly adjusted, will not assume, on being suspended freely in the plane of the meridian, the direction which magnetism alone would have imparted to it, and that it will, in consequence, err sensibly from the true dip; the remedy which has been recommended for this inconvenience, and which has become the usual practice, is to reverse the poles of the needle, and to take the arithmetical mean of the arcs indicated in four positions, as the true magnetic dip. The sanction of this method by persons who are regarded as authorities, is a sufficient indication, that observations of the dip

were considered by them merely as approximations; since it could not have been otherwise overlooked, that the arithmetical mean is in no case the result which is strictly deducible from the arcs, and that, in many instances, it must differ considerably from the more correct deduction; whilst the adoption of this method in general practice, has charged the results with an error, which might have been avoided; the amount of which can only now be known, when the details of the observation have been given, and furnish the means of re-computation.

The perfect balancing of the needle is sometimes attempted by a cross of wires affixed to the axis, as described in the Philosophical Transactions for 1772, Article 35; but this contrivance is more ingenious than useful in practice, and introduces a liability to errors, of far more importance than the inconveniencies which it was designed to obviate. The adjustment of the balance, after the needle is magnetised, is in itself a troublesome, tedious, and uncertain operation, and is far too subject to derangement to be confided in, when the instrument has been removed from station to station; moreover, the inaccuracies occasioned by friction, are augmented by the additional weight of the mechanism on the one arm of the axis, and of a counterweight on the other. The errors of an imperfect balance are reducible by calculation, but those of friction are not so; whether they may arise from the axis not being truly cylindrical, or from the inequalities of its surface producing a resistance on the planes, which the moving force of the needle is not fully adequate to overcome. It may be, therefore, justly remarked, that the true and unimpeded motion of the axis, and the consequent

return of a needle in successive trials to the same division of the limb, is one of the principal qualifications of a good dipping needle.

Having been convinced by the trial of several needles, that the disagreement in their results was chiefly to be attributed to the various causes of inaccuracy in the motion of the axis, I requested Mr. DOLLOND to make a needle on a construction suggested, from similar experience, by Professor J. TOBIAS MEYER, in his treatise "de usu accuratiori acûs inclinatoriæ Magneticæ," published in the Transactions of the Royal Society of Sciences at Gottingen for 1814. The experiments which are now submitted to the Royal Society were made with this needle, which, for simplicity of construction, convenience in use, and consistency of results, appears to deserve a preference over those which have been hitherto employed.

As the needle which Mr. DOLLOND made, differed in some few particulars from the construction recommended by Professor MEYER, it may be proper to prefix a short description of it, as well as of the mode of observation.

The needle is a parallelopipedon of eleven inches and a half in length, four tenths in breadth, and one twentieth in thickness; the ends are rounded; and a line marked on the face of the needle passing through the centre to the extremities, answers the purpose of an index.

The cylindrical axis on which the needle revolves, is of bell metal, terminated, where it rests on the agate planes, by cylinders of less diameter; the finer these terminations are made, so long as they do not bend with the weight of the needle, the more accurate will be the oscillations; small

grooves in the thicker part of the axis receive the Y's, which raise and lower the needle on its supports, and ensure that the same parts of the axis rest in each observation on the planes.

A small brass sphere traverses on a steel screw, inserted in the lower edge of the needle, as nearly as possible in the perpendicular to the index line passing through the axis of motion; by this mechanism, the centre of gravity of the needle, with the screw and sphere, may be made to fall more or less below the axis of motion, according as the sphere is screwed nearer or more distant from the needle, and according as spheres of greater or less diameter are employed.

The object proposed in thus separating the centres of motion and gravity, is to give to the needle a force arising from its own weight to assist that of magnetism in overcoming the inequalities of the axis, and thus to cause the needle to return, after oscillation, with more certainty to the same point of the divided limb, than it would do were the centres strictly coincident.

The centres of motion and of gravity not coinciding, the position which the needle assumes, when placed in the magnetic meridian, is not that of the dip: but the dip is deducible, by an easy calculation, from observations made with such a needle, according to the following directions.

If the needle has been carefully made, and the screw inserted truly as described, the centres of motion and of gravity will be disposed as in the lever of a balance, when a right line joining them will be a perpendicular to the horizontal passing through the extremities (or to the index line); this

condition is not indeed a necessary one, but it is desirable to be accomplished, because it shortens the observations, as well as the calculation, from whence the dip is deduced; its fulfilment may be ascertained with great precision by placing the needle on the agate planes before magnetism is imparted to it, and observing whether it returns to a horizontal direction, after oscillation in each position of the axis; if it does not, it may be made to do so at this time with no great trouble.

With a needle in which this adjustment can be relied on, two observations made in the magnetic meridian are sufficient for the determination of the dip, the two faces of the needle being successively towards the observer, reversing the position of the axis on its supports in such manner that the edge of the needle which is uppermost in the one observation becomes lowermost in the other; the angles which the needle makes with the vertical in these two positions being read, the mean of the tangents of those angles is the co-tangent of the dip.

But when needles are used in which this adjustment has not been made, or where its accuracy cannot be relied on, four observations are required; two being those which are already directed; the two others are similar to them, but with the poles of the needle reversed; calling then the first arcs F and $f$, and those with the poles reversed G and $g$, and taking

$$\text{tang } F + \tan f = A$$
$$\text{tang } F - \tan f = B$$
$$\text{tang } G + \tan g = C$$
$$\text{tang } G - \tan g = D$$

$$\frac{A.D}{B+D} + \frac{B.C}{B+D} = \text{twice the co-tangent of the dip.}$$

The demonstration of this formula is given in the treatise which has been referred to; the investigation is simple.

In reversing the poles, it is not necessary that the magnetic force imparted to the needle should be the same in amount as it possessed previously to the operation.

By adopting the precaution of placing the needle in a groove to prevent its lateral motion, and by confining the sides of the magnet by parallel strips of wood, so that in moving along the needle they may preserve its direction, the poles may always be ensured to coincide with the extremities of the longitudinal axis.

It is desirable to be furnished with several spheres of different diameters, to possess the means of proportioning the force, arising from the eccentricity, to the force of magnetism, as the latter is doubled between the equator and the poles; it may be expedient that the force of magnetism should always predominate, though no such inference appears to result from the present experiments, in which eight spheres were used, numbered according to size, No. 1 being the largest.

If the distance between the centres of motion and of gravity be considerable, the arcs in the alternate observations will be on different sides of the vertical, especially where the dip is great; in such cases the arcs to the south of the vertical are read negatively.

The instrument in which the needle was tried is already described in the Philosophical Transactions for 1819, page 192, and several improvements which have been since added, in the Appendix to Captain PARRY's Voyage of Discovery, pages cvii. cxxxix., &c.; the perfect horizontality of the

agate planes, and the adjustments of the zeros of the circle were verified in every change of position of the instrument by the double cone apparatus described in page cxl., which proves very convenient in use, and is highly conducive to accuracy; the circle is divided into spaces of twenty minutes, but by means of a moveable lens, the arcs to which the needle settles can be read off, with tolerable correctness, to minutes; the arcs, in each of the four positions forming the elements from whence the dip is deduced, are the arithmetical mean of (usually) six observations, half of which are with the face of the circle towards the east, and half with the face towards the west; the needle being lifted by the Y's and lowered gently on its supports between each observation; the arcs indicated by both ends of the needle are also read, to correct the errors arising from inequality in the divisions, or from the axis of the needle not passing correctly through the centre of the circle.

The experiments were made in the nursery garden in the Regent's Park, by permission of Mr. JENKINS, the proprietor. The situation is in all respects an eligible one, being far removed from the neighbourhood of iron.

The two first experiments are given in detail, that the method of observation may be more fully exemplified.

*Experiment* 1. *August 3d*, 1821, with sphere No. 8, midway between the edge of the needle and the end of the screw. In this experiment all the arcs were on the north side of the vertical, and were therefore all read positively.

| | Face A of the Needle towards the Observer. | | | Face B towards the Observer. | | |
|---|---|---|---|---|---|---|
| | N. end | S. end | | N. end | S. end | |
| | ° ′ | ° ′ | | ° ′ | ° ′ | |
| Face of the Circle East | 31 00 | 30 52 | | 9 18 | 9 18 | |
| | 31 00 | 30 52 | | 9 17 | 9 15 | |
| | 31 00 | 30 52 | | 9 20 | 9 19 | |
| | 31 02 | 30 55 | | 9 24 | 9 22 | |
| | 31 00 | 30 52 | | 9 24 | 9 23 | |
| | 31 02 | 30 56 | | 9 19 | 9 18 | |
| Face West | 31 25 | 31 20 | | 9 25 | 9 30 | |
| | 31 20 | 31 13 | | 9 25 | 9 30 | |
| | 31 20 | 31 13 | | 9 22 | 9 22 | |
| | 31 22 | 31 15 | | 9 21 | 9 22 | |
| | 31 24 | 31 17 | | 9 25 | 9 30 | |
| | 31 26 | 31 20 | | 9 25 | 9 30 | |
| | 31 11,7 | 31 04,8 | | 9 22,1 | 9 22,4 | |
| | | 31 08,2 = F | | | 9 22,3 = *f*. | |

*Poles Inverted.*

| | | | | | |
|---|---|---|---|---|---|
| | ° ′ | ° ′ | | ° ′ | ° ′ |
| Face West | 30 15 | 30 05 | | 5 20 | 5 23 |
| | 30 12 | 30 00 | | 5 17 | 5 20 |
| | 30 10 | 30 00 | | 5 20 | 5 23 |
| | 30 10 | 30 00 | | 5 22 | 5 26 |
| | 30 10 | 30 00 | | 5 22 | 5 27 |
| | 30 16 | 30 04 | | 5 18 | 5 22 |
| Face East | 29 20 | 29 10 | | 7 15 | 7 10 |
| | 29 21 | 29 11 | | 7 12 | 7 12 |
| | 29 21 | 29 12 | | 7 13 | 7 15 |
| | 29 19 | 29 08 | | 7 13 | 7 14 |
| | 29 24 | 29 17 | | 7 14 | 7 14 |
| | 29 19 | 29 08 | | 7 14 | 7 14 |
| | 29 46,4 | 29 36,3 | | 6 16,6 | 6 18,3 |
| | | 29 41,3 = G | | | 6 17,4 = *g* |

Here $\tan F = \tan 31^\circ\ 08',2 = 0{,}60411$; and $\tan G = \tan 29^\circ\ 41',3 = 0{,}57012$

$\tan f = \tan\ 9\ 22,3 = 0{,}16504$; $\tan g = \tan\ 6\ 17,4 = 0{,}11022$

$\tan F + \tan f = A = 0{,}76915$; $\tan G + \tan g = C = 0{,}68034$

$\tan F - \tan f = B = 0{,}43907$; $\tan G - \tan g = D = 0{,}4599$

$B + D = 0{,}89897$

And $\frac{AD}{B+D} + \frac{BC}{B+D} = \frac{0,76915 \times 0,4599}{0,89897} + \frac{0,68034 \times 0,43907}{0,89897} = 0,39348$
$+ 0,33229 = 0,72577$ = twice the cotangent of the dip; therefore, $\frac{0,72577}{2} = 0,36288$; cot. of 70° 09′, 8 north dip.

*Experiment* 2. *August 6th*, 1821, with sphere No. 1, screwed up close to the needle; in this experiment the alternate arcs were on the south side of the vertical, and were therefore read and used negatively.

| | Face A towards the observer. | | Face B towards the observer. | |
|---|---|---|---|---|
| | ° ′ | ° ′ | ° ′ | ° ′ |
| Face of the Circle East | N. end 49 20 | S. end 49 00 | N. end —22 14 | S. end —22 06 |
| | 49 20 | 49 00 | —22 14 | —22 06 |
| | 49 22 | 49 02 | —22 17 | —22 12 |
| Face West | 49 22 | 49 04 | —22 40 | —22 20 |
| | 49 22 | 49 03 | —22 40 | —22 20 |
| | 49 22 | 49 04 | —22 38 | —22 18 |
| | 49 21,3 | 49 02,1 | —22 27,1 | —22 17 |
| | 49 11,7 = F | | —22 22 = *f*. | |

*Poles inverted.*

| | ° ′ | ° ′ | ° ′ | ° ′ |
|---|---|---|---|---|
| Face West | 47 15 | 47 00 | —20 20 | —20 10 |
| | 47 20 | 47 00 | —20 20 | —20 08 |
| | 47 14 | 46 56 | —20 20 | —20 04 |
| Face East | 47 00 | 46 40 | —20 10 | —20 00 |
| | 47 00 | 46 40 | —20 10 | —19 58 |
| | 47 00 | 46 40 | —20 10 | —19 58 |
| | 47 08,1 | 46 49,3 | —20 15 | —20 03 |
| | 46 58,7 = G | | —20 09 = *g* | |

Here $\tan F = \tan 49\ 11,7 = 1,15831$; and $\tan G = \tan 46\ 58,7 = 1,07156$
$\tan f = \tan -22\ 22 = -0,41149$ $\tan g = \tan -20\ 09 = -0,36694$
$\tan F + \tan f = A = 0,74682$ $\tan G + \tan g = C = 0,70462$
$\tan F - \tan f = B\ 1,5698$ $\tan G - \tan g = D = 1,4385$

$B + D = 3,0083$

$\frac{AB}{B+D} + \frac{BC}{B+D} = \frac{0,74682 \times 1,4385}{3,0083} + \frac{0,70462 \times 1,5698}{3,0083} = 0,35711$
$+ 0,36769 = 0,7248$; $\frac{0,7248}{2} = 0,3624$ cot. of 70 04,7 N. dip.

*Abstract of ten experiments with* MEYER'S *needle.*

| | | | | | | |
|---|---|---|---|---|---|---|
| Exp. 1. Aug. 3. | Sphere 8 screwed half up. | Marked end of the Needle being a. | N. Pole; F = 31 08,2 and S. Pole; G = 29 41,3 | $f$ = + 9 23,3 and $g$ = + 6 17,4 | 70 03, 3 N. |
| Exp. 2. Aug. 6. | Sphere 1 close to the Needle. | —— | N. Pole; F = 49 11,7 and S. Pole; G = 46 58,7 | $f$ = −22 22 and $g$ = −20 09 | 70 04, 7 |
| Exp. 3. Aug. 6. | Sphere 8 nearly as in the 1st Experiment. | —— | N. Pole; F = 30 36,8 and S. Pole; G = 28 47,7 | $f$ = + 10 08,3 and $g$ = + 7 46,6 | 70 01, 4 |
| Exp. 4. Aug. 11. | Sphere 3 close to the Needle. | —— | N. Pole; F = 45 58 and S. Pole; G = 41 50,7 | $f$ = −14 49,1 and $g$ = −11 28,7 | 70 00, 1 |
| Exp. 5. Aug. 13. | Sphere 7 close to the Needle. | —— | N. Pole; F = 27 24,3 and S. Pole; G = 24 14,2 | $f$ = + 14 07,2 and $g$ = + 13 21,7 | 70 05, 9 |
| Exp. 6. Aug. 13. | Sphere 6 close to the Needle. | —— | N. Pole; F = 30 36,2 and S. Pole; G = 27 12,6 | $f$ = + 10 17,2 and $g$ = + 9 15,3 | 70 03, 5 |
| Exp. 7. Aug. 15. | Sphere 5 close to the Needle. | —— | N. Pole; F = 32 00,2 and S. Pole; G = 28 57,4 | $f$ = + 8 03,4 and $g$ = + 7 40,9 | 70 05, 2 |
| Exp. 8. Aug. 15. | No Sphere; weight of the screw close. | —— | N. Pole; F = 24 14 and S. Pole; G = 22 17,5 | $f$ = + 17 34,1 and $g$ = + 15 34,8 | 70 00, 9 |
| Exp. 9. Aug. 20. | Sphere 1 close to the Needle. | —— | N. Pole; F = 48 24,7 and S. Pole; G = 44 57,1 | $f$ = −19 25 and $g$ = −17 19 | 70 00, 3 |
| Exp. 10. Aug. 20. | Sphere 7 close to the Needle | —— | N. Pole; F = 24 27,6 and S. Pole; G = 22 04 | $f$ = + 17 38,5 and $g$ = + 15 22 | 70 03, 8 |

Dip in London, August 1821 = 70 02,91 N.

Note. The screw on which the spheres traversed was made, in the first instance, half an inch in length, but was shortened one half after the third experiment; being found still longer than necessary, it was again shortened after the eighth experiment, until its length just equalled the diameter of the largest sphere.

Being desirous to confirm the correctness of the result obtained with MEYER'S needle, I made the following experiments for the purpose of deducing at least an approximation of the dip by a method suggested, I believe, originally by LAPLACE, of observing the times in which a certain number of oscillations are made by a dipping needle, in the magnetic meridian, and in the plane perpendicular to it.

The force acting on the needle in the latter case is reduced, according to the principles of the resolution of forces, in the ratio of the radius to the sine of the dip; whence calling M the time in which a certain number of vibrations are made in the meridian, P the corresponding time in the perpendicular plane, and D the dip, $\frac{M^2}{P^2} = \text{sine D}$.

In all the subsequent experiments, the needles were retained and released at an angle of 40° with the meridian, by an apparatus for that purpose fitted to the instrument, and were suffered to oscillate until the arc of vibration was reduced to 30° before the account was taken up, and the observation commenced.

*Exp.* 1. *Sept.* 3d, with a dipping needle, the centre of gravity of which was rendered nearly coincident with the axis of motion, by a slider of silk advanced towards the end which was previously too light, until the needle in the meridian stood at 70° nearly, and became vertical when the instrument was moved 90° in azimuth.

*In the meridian.*

| Oscill. | 1 Arc. | 1 Time. | 1 Int. | 2 Arc. | 2 Time. | 2 Int. | 3 Arc. | 3 Time. | 3 Int. |
|---|---|---|---|---|---|---|---|---|---|
| | ° | m s | s | ° | m s | s | ° | m s | s |
| 0 | 30 | 0 00 | | 30 | 0 00 | | 30 | 0 00 | |
| | | | 55,5 | | | 55 | | | 55,5 |
| 10 | 24 | 0 55,5 | | 23 | 0 55 | | 24 | 0 55,5 | |
| | | | 55 | | | 55 | | | 55 |
| 20 | 20 | 1 50,5 | | 20 | 1 50 | | 21 | 1 50,5 | |
| | | | 55 | | | 55 | | | 55 |
| 30 | 17 | 2 45,5 | | 16 | 2 45 | | 17 | 2 45,5 | |
| | | | 54,5 | | | 54,5 | | | 55 |
| 40 | 14 | 3 40 | | 13 | 3 39,5 | | 14 | 3 40,5 | |
| | | | 54 | | | 54,5 | | | 54,5 |
| 50 | 10 | 4 34 | | 10 | 4 34 | | 10 | 4 35 | |
| 50 Oscillations in | | 274 | | | 274 | | | 275 seconds. | |

M = 274,33.

*Perpendicular to the meridian.*

| Oscill. | 1 Arc. | 1 Time. | 1 Int. | 2 Arc. | 2 Time. | 2 Int. |
|---|---|---|---|---|---|---|
| | ° | m s | s | ° | m s | s |
| 0 | 30 | 0 00 | | 28 | 0 00 | |
| | | | 57 | | | 57 |
| 10 | 25 | 0 57 | | 22 | 0 57 | |
| | | | 57 | | | 57 |
| 20 | 20 | 1 54 | | 18 | 1 54 | |
| | | | 56,5 | | | 56,5 |
| 30 | 16 | 2 50,5 | | 16 | 2 50,5 | |
| | | | 56,5 | | | 56,5 |
| 40 | 14 | 3 47 | | 14 | 3 47 | |
| | | | 56 | | | 56 |
| 50 | 11 | 4 43 | | 10 | 4 43 | |
| 50 Oscillations in | | 283 ..... | | ..... | 283 seconds. | |

P = 283

$\frac{M^2}{P^2} = \frac{274,33^2}{283^2} = ,93966$ sine of 69°.59′,7. N. dip.

*Experiment* 2. *Sept. 7th*, with a dipping needle, (No. 2,) balanced by a cross of wires affixed to the axis.

*In the meridian.*

| Oscill. | 1 Arc. | 1 Time. | 1 Int. | 2 Arc. | 2 Time. | 2 Int. | 3 Arc. | 3 Time. | 3 Int. |
|---|---|---|---|---|---|---|---|---|---|
| | ° | m s | s | ° | m s | s | ° | m s | s |
| 0 | 30 | 0 00 | | 30 | 0 00 | | 30 | 0 00 | |
| | | | 50 | | | 50 | | | 50 |
| 10 | 22 | 0 50 | | 21 | 0 50 | | 25 | 0 50 | |
| | | | 49,5 | | | 49 | | | 49 |
| 20 | 17 | 1 39,5 | | 16 | 1 39 | | 18 | 1 39 | |
| | | | 48,5 | | | 48,5 | | | 49 |
| 30 | 13 | 2 28 | | 12 | 2 27,5 | | 12 | 2 28 | |
| | | | 49 | | | 49,5 | | | 49 |
| 40 | 10 | 3 17 | | 9 | 3 17 | | 10 | 3 17 | |
| | | | 49 | | | 49 | | | 49 |
| 50 | 6 | 4 06 | | 6 | 4 06 | | 7 | 4 06 | |
| | | | 50 | | | 50,5 | | | 50 |
| 60 | 4 | 4 46 | | 4 | 4 56,5 | | 5 | 4 56 | |
| | | | 50 | | | 50 | | | 50 |
| 70 | 2 | 5 46 | | 2 | 5 46,5 | | 3 | 5 46 | |
| 70 Oscillations in | | 346 | | | 346,5 | | | 346 | seconds. |

$M = 346{,}17$

*Perpendicular to the meridian.*

| Oscill. | 1 Arc. | 1 Time. | 1 Int. | 2 Arc. | 2 Time. | 2 Int. | 3 Arc. | 3 Time. | 3 Int. |
|---|---|---|---|---|---|---|---|---|---|
| | ° | m s | s | ° | m s | s | ° | m s | s |
| 0 | 30 | 0 00 | | 30 | 0 00 | | 30 | 0 00 | |
| | | | 51 | | | 50,5 | | | 52 |
| 10 | 22 | 0 51 | | 23 | 0 50,5 | | 23 | 0 52 | |
| | | | 50,5 | | | 51,5 | | | 51 |
| 20 | 15 | 1 41,5 | | 18 | 1 42 | | 17 | 1 43 | |
| | | | 52 | | | 51 | | | 51 |
| 30 | 10 | 2 33,5 | | 12 | 2 33 | | 12 | 2 34 | |
| | | | 51 | | | 51 | | | 51 |
| 40 | 8 | 3 24,5 | | 8 | 3 24 | | 9 | 3 25 | |
| | | | 51 | | | 51 | | | 52 |
| 50 | 6 | 4 15,5 | | 6 | 4 15 | | 6 | 4 17 | |
| | | | 51 | | | 51 | | | 50 |
| 60 | 4 | 5 06,5 | | 4 | 5 06 | | 3 | 5 07 | |
| | | | 50,5 | | | 51 | | | 50 |
| 70 | 2 | 5 17 | | 2 | 5 57 | | 2 | 5 57 | |
| 70 Oscillations in | | 357 | | | 357 | | | 357 | seconds. |

$P = 357.$

$$\frac{M^2}{P^2} = \frac{346{,}17^2}{357^2} = .94025 \text{ sine of } 70^\circ\ 05',8 \text{ N. dip.}$$

*Exp.* 3, *Sept.* 7, with a dipping needle (No. 3.) made by Mr. DOLLOND, the arms of which were conical, having at their common base a small cube perforated to receive the axis; the cylindrical terminations of the axis were similar to those of MEYER's needle, very slender, and very carefully turned.

*In the meridian.*

| Oscill. | 1 Arc. | 1 Time. | 1 Int | 2 Arc. | 2 Time. | 2 Int. | 3 Arc. | 3 Time. | 3 Int. | 4 Arc. | 4 Time. | 4 Int. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | o | m s | " | o | m s | " | o | m s | " | o | m s | " |
| 0 | 28 | 0 00 | | 27 | 0 00 | | 27 | 0 00 | | 28 | 0 00 | |
| | | | 37 | | | 38 | | | 37,5 | | | 37 |
| 10 | 23 | 0 37 | | 22 | 0 38 | | 21 | 0 37,5 | | 23 | 0 37 | |
| | | | 38 | | | 37 | | | 37 | | | 37 |
| 20 | 19 | 1 15 | | 19 | 1 15 | | 16 | 1 14,5 | | 18 | 1 14 | |
| | | | 37 | | | 37 | | | 37,5 | | | 37 |
| 30 | 16 | 1 52 | | 16 | 1 52 | | 14 | 1 52 | | 15 | 1 51 | |
| | | | 37 | | | 37,5 | | | 37,5 | | | 38 |
| 40 | 14 | 2 29 | | 14 | 2 29,5 | | 11 | 2 29,5 | | 13 | 2 29 | |
| | | | 37 | | | 37,5 | | | 37 | | | 37 |
| 50 | 12 | 3 06 | | 12 | 3 07 | | 8 | 3 06,5 | | 10 | 3 06 | |
| | | | 37 | | | 37 | | | 37 | | | 37 |
| 60 | 10 | 3 43 | | 10 | 3 44 | | 6 | 3 43,5 | | 8 | 3 43 | |
| | | | 37 | | | 36,5 | | | 37 | | | 37 |
| 70 | 8 | 4 20 | | 8 | 4 20,5 | | 4 | 4 20,5 | | 6 | 4 20 | |
| 70 Oscillations in | | 260 | | | 260,5 | | | 260,5 | | | 260 | seconds. |

M = 260,25.

*Perpendicular to the meridian.*

| Oscill. | 1 Arc. | 1 Time. | 1 Int. | 2 Arc. | 2 Time. | 2 Int. | 3 Arc. | 3 Time. | 3 Int. | 4 Arc. | 4 Time. | 4 Int. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | o | m s | " | o | m s | " | o | m s | " | o | m s | " |
| 0 | 30 | 0 00 | | 27 | 0 00 | | 27 | 0 00 | | 28 | 0 00 | |
| | | | 39,5 | | | 39 | | | 38,5 | | | 39 |
| 10 | 27 | 0 39,5 | | 22 | 0 39 | | 23 | 0 38,5 | | 24 | 0 39 | |
| | | | 38,5 | | | 39 | | | 39 | | | 39 |
| 20 | 22 | 1 18 | | 17 | 1 18 | | 19 | 1 17,5 | | 21 | 1 18 | |
| | | | 39 | | | 38 | | | 38,5 | | | 38 |
| 30 | 19 | 1 57 | | 14 | 1 56 | | 16 | 1 56 | | 17 | 1 56 | |
| | | | 38 | | | 39 | | | 38,5 | | | 38 |
| 40 | 15 | 2 35 | | 12 | 2 35 | | 14 | 2 34,5 | | 15 | 2 34 | |
| | | | 37 | | | 38 | | | 38 | | | 38 |
| 50 | 11 | 3 12 | | 8 | 3 13 | | 11 | 3 12,5 | | 12 | 3 12 | |
| | | | 38 | | | 37 | | | 38 | | | 38 |
| 60 | 9 | 3 50 | | 6 | 3 50 | | 9 | 3 50,5 | | 10 | 3 50 | |
| | | | 38,5 | | | 38 | | | 38 | | | 38,5 |
| 70 | 6 | 4 28,5 | | 4 | 4 28 | | 7 | 4 28,5 | | 8 | 4 28,5 | |
| 70 Oscillations in | | 268,5 | | | 268 | | | 268,5 | | | 268,5 | seconds. |

P = 268,38.

$$\frac{M^3}{P^3} = \frac{260{,}25^3}{268{,}38^3} = 94033 \text{ sine of } 70^\circ\ 06',5 \text{ N. dip.}$$

Mean of the preceding results.

| | | |
|---|---|---|
| Experiment 1. | 69° 59′,7 | 70° 04′ N. dip. |
| Experiment 2. | 70 05,8 | |
| Experiment 3. | 70 06,5 | |

This was a nearer accordance with the direct observation with MEYER's needle than I had anticipated. As this method, which is highly deserving of adoption in the lower magnetic latitudes, must become far less certain in parallels so high as 70°, when a very small alteration in either of the observed times will produce a wide difference in the conclusion: unless, therefore, the oscillation of a needle in suitable arcs can be continued through a number of seconds, much exceeding those of the preceding experiments, the result may be liable, without great care and frequent repetition, to considerable error.

I am not aware that a method of deducing the dip on a similar principle, but possessing the same advantages in the high latitudes as the former does between the magnetic equator and 45° (nearly), has been heretofore suggested: it is by observing the times in which a certain number of oscillations are made by the same needle in the following positions; first, when used as a dipping needle, vibrating in the plane of the meridian; and, secondly, when suspended horizontally by a silk thread attached to either end of the axis, the needle being limited thereby to a horizontal motion.

The square of the times of horizontal vibration being increased, as the radius to the *cosine* of the dip, it is obvious, that, as in the former method, the effect of errors of observation on the result increases with the angle of the dip,

according as the differences of the sines progressively diminish; so in this method, on the contrary, the influence of such errors will be lessened in the same ratio: thus in dips of 65° and upwards, the determination may be made with very considerable accuracy, with instruments generally of good construction, and with needles of which the terminations of the axis are very slender.

The horizontal vibrations should be made under a cover of glass, or of wood with glass windows; the silk suspension should be several inches in length, and perfectly free from twist.

The following experiment was made with the needle numbered 9 in the preceding; the silk line was 15 inches in length, and was fastened in a groove near the end of the axis; the oscillations were made in arcs under 25°.

| Oscil. | Times. | | Oscil. | Times. | | | |
|---|---|---|---|---|---|---|---|
| | m | s | | m | s | | m s |
| 0 | 0 | 00 | 70th | 7 | 25,75 | 70 oscil. in | 7 25,5 |
| 2nd | 0 | 13 | 72d | 7 | 38,5 | | |
| 4th | 0 | 25,75 | 74th | 7 | 51,25 | | |
| 6th | 0 | 38,5 | 76th | 8 | 04 | | |
| 8th | 0 | 51,25 | 78th | 8 | 16,75 | | |
| 10th | 1 | 04 | 80th | 8 | 29,25 | | |

Here making $7^{m}\ 25{,}5 = 445{,}5^{s} = H$, and M as before $= 260{,}25^{s}$, $\frac{M^2}{H^2} = \frac{260{,}25^2}{445{,}5^2} = {}'341265$ cosine of 70° 02′,6 N. dip.

The results by the three different methods collected in one view, are as follow, viz:

| | |
|---|---|
| By 10 experiments with MEYER's needle | 70° 02′.9 |
| By the times of oscillation in the magnetic meridian and in the plane perpendicular to it; mean by three needles. | 70,04 |
| By the times of vertical and horizontal oscillation | 70,02,6 |

Whence 70° 03′ may be considered as the mean dip of the needle towards the north in the Regent's Park, in August and September 1821, within four hours of noon, being the limit within which all the experiments were made.

In referring to the observations which are recorded to have been made for the purpose of determining the dip in London in former years, those of Mr. NAIRNE, in 1772, of Mr. CAVENDISH, in 1776, and of Mr. GILPIN, in 1805, appear to have received, and to be deserving of, principal consideration; the errors by which these several determinations may have been affected, in consequence of the imperfections of the instruments, may be believed to have been confined within limits of no great extent, by the method of the observers, and by the precautions which they adopted; as, however, the observations were made in houses in close built parts of the metropolis, they were all subject to the influence of local attraction, from whence may have originated errors of greater consequence possibly than those of the instruments; nor can the application of a correction found by observing the difference of the dip, on the outside of the house, be considered an effectual remedy, inasmuch as the needle may still have been attracted by iron in the adjoining houses, or in the neighbourhood. It needs only to try needles in different situations in a city, to be convinced how little dependance should be placed in the accuracy of such results; it may, no doubt, be principally owing to this cause, rather than to instrumental error, that the dip at the Apartments of the Royal Society is stated in the Philosophical Transactions for the present year (1821), to be 71° 6′ or 71° 42′.

As the observations of Mr. NAIRNE, in 1772, and of Mr. CAVENDISH, in 1776, do not differ very widely from each

other, either in the date, or in the amount of the dip, their mean, 72° 25′, in 1774, may be considered as the best approximation which can now be made to a knowledge of the amount of the dip in London at an early period.

By comparing this amount with the dip in the present year as above determined, we obtain 3′,02 as a mean annual rate of diminution between 1774 and 1821; which is less by two-fifths than the mean annual diminution at Paris between the years 1798 and 1814, as deduced from the observations of Messrs. Humboldt, Gay Lussac, and Arago; whence it might be inferred, if sufficient dependance could be placed on the accuracy of the observations, that the annual variation of the dip in this part of the world, is greater now than it was 30 or 40 years since.

It is, however, worthy of notice, as being at least a curious coincidence, that if we take Mr. Whiston's determination of the dip in 1720, 75° 10′ (of which Mr. Cavendish remarked in the Philosophical Transactions for 1776, Art. 21,) that "he believed it to have been pretty accurate, as Mr. Whiston observed in many parts of the kingdom, and his observations agreed well together," we obtain between the years 1720 and 1774, an annual diminution of 3′,05, which differs only three hundredths of a minute from the rate which has been now found for the succeeding 47 years.

It may not be useless, briefly to examine how far the knowledge of the amount of change, by direct observation, is capable of receiving confirmation by the effect which a diminution of dip must produce on the vibrations of a needle suspended horizontally.

If the intensity of the magnetic force be considered to vary

in the ratio suggested by Dr. YOUNG, inversely as the square root of four diminished by three times the square of the sine of the dip, which ratio has been remarkably confirmed in dips from 70 to 90 degrees, by the experiments made during the late Arctic voyage; the force acting on the horizontal needle, being reduced as the radius to the cosine, becomes inversely as $\sqrt{\frac{1}{1-s^2}+3}$; $s$ being the sine of the dip; whence, in London, the duration of any number of horizontal vibrations would be increased by about $\frac{1}{3000}$ part, on a reduction of one minute in the dip.

The needle No. 3. of the preceding experiments, suspended in the manner therein described, and released at an arc of 40° from the meridian, will continue to vibrate more than forty minutes, making upwards of 400 vibrations, before the arcs become so small as to render the completion of each vibration indistinct. If the times of commencement and conclusion are observed in the method exemplified in the experiment with this needle, page 17; the duration of any number of vibrations may be readily and accurately determined to a part of a second; if, therefore, 400 be taken as the experimental number, and the duration be supposed 42 minutes, or 2520 seconds, the reduction of 3 minutes of dip, which is presumed to take place annually, would cause an increase of two seconds and two-tenths in the time of vibration; which difference may, perhaps, be considered sufficient to encourage the experiment, especially if a mean be taken of many observations in each year; in which case it may be advisable to compare together observations made at the same season in successive years; and perhaps, also, at the same hour of the day; although the experiments of Messrs. HUMBOLDT and

Gay Lussac have shown, that if any hourly variation of the force does obtain, it is not sufficient to produce a perceptible effect in a time of vibration amounting to 1234 seconds, repeated at different hours of the day and night.

In conclusion, there appears reason to presume from the preceding experiments, that the dip itself may be determined by Meyer's needle within a much smaller limit of uncertainty, than has hitherto been the case by needles of the usual construction; as the results are subject only to those errors, which are reducible by repetition; for in the ten experiments which have been submitted to the Society, the greatest difference of any one from the mean does not exceed three minutes; the direct observation may, therefore, be considered as capable of sufficient precision, to justify inferences from repetition, at intervals of short duration; both of the amount, and also of the uniformity, of the changes to which the dip is subject.

## II. *Some positions respecting the influence of the Voltaic Battery in obviating the effects of the division of the eighth pair of nerves. Drawn up by* A. P. Wilson Philip, *M. D. F. R. S. Edin. Communicated by* B. C. Brodie, *Esq. F. R. S.*

Read July 5, 1821.

Dr. Philip finding that Mr. Brodie did not think what had been done sufficient to establish certain positions which Dr. Philip had stated, he, for Mr. Brodie's satisfaction, and with his assistance, entered on an investigation, with respect to the results of which, Mr. Brodie agrees with him. They were the following.

In some experiments in which the nerves of the eighth pair were divided in the neck of a rabbit, and the ends not displaced, and the animal was allowed to live some hours, it was found that food swallowed immediately before the division of the nerves, was considerably digested, even when the divided ends of the nerves had retracted to the distance of a quarter of an inch from each other.

In other experiments in which, after the division of the nerves, the divided ends had been turned completely away from each other, little or no perfectly digested food, when the animal was allowed to live some hours, was found in the stomach; and the longer the animal lived, the smaller was the proportion of digested food found in the stomach; the great mass having the appearance of masticated food, which was not sensibly lessened in quantity, however long the

animal lived. In an experiment in which, under such circumstances, the stomach was exposed, from the time of the division of the nerves, to the influence of a voltaic battery sent through the lower portion of the divided nerves, its contents were apparently as much changed as they would have been in the same time in the healthy animal. The change was also of the same kind, the contents of the stomach assuming a dark colour, and those of the pyloric end being more uniform, and of a firmer consistence than those of the central and cardiac portions of the stomach, while the whole contents became less in quantity.

The division of the nerves, in both ways, produced difficulty of breathing and efforts to vomit; neither of which occurred when the stomach and lungs were brought under the influence of a voltaic battery, sent through the lower portion of the divided nerves.*

When, under the foregoing circumstances, the lungs had not been exposed to the voltaic influence, and the animal had been allowed to live for five or six hours, they were found much congested: in the rabbit which had been submitted to this influence, they seemed quite healthy.

* Mr. Brodie was not present till after the death of the animal, but this fact was observed by Mr. Broughton and others.

III. *On some alvine concretions found in the colon of a young man in Lancashire, after death. By* J. G. CHILDREN, *Esq. F. R. S. &c. &c. Communicated by the Society for Promoting Animal Chemistry.*

Read December 18, 1821.

I WAS furnished with the particulars of the following case, through the kindness of JAMES THOMSON, Esq. of Primrose, near Clitheroe.

JOHN CHAMBERS, aged 19, a carpenter at Clitheroe, in Lancashire, was in the habit, during the hot weather of July 1814, of refreshing himself whilst at work, by eating a quantity of unripe plums, of which, at various times, he ate several quarts, and generally swallowed the stones, under the erroneous notion entertained by the lower classes in that neighbourhood, that they would assist the digestion of the fruit. A fellow workman of CHAMBERS, aged 30, pursued the same practice with impunity. Not so the unfortunate subject of this communication, who about Christmas began to complain, but still pursued his occupation and worked, with some interruption, till February 1815, when he applied to Mr. COULTATE, of Clitheroe, for advice, complaining of pain in the abdomen attended with diarrhœa. The abdomen on examination felt tense but not much enlarged, nor had he any feverish symptoms. When in the workshop, he used to lean against the bench, pressing his stomach hard against it, which, he said,

afforded him great relief. Medicines of an astringent nature were first prescribed, which seemed for a time to be of service, but the diarrhœa ere long increased, extreme emaciation took place, and a hard circumscribed tumour was discovered on one side of the abdomen, which, from the thinness of the abdominal parietes, Mr. COULTATE could distinctly feel was an alvine concretion. Clysters were then administered, castor oil given, and the abdomen ordered to be rubbed with oil, under the idea of pushing the concretions forward, but in vain; the patient daily became more and more emaciated, and after about three months attendance he died, on the 6th of May, completely worn out. His appetite was good, or rather almost voracious, even to within a very short time of his death. He always felt himself worse after meals. His stools, especially for some weeks before he expired, were like blood and water. He was confined to his bed for about three weeks before he died. On opening the body, the concretions were found lodged in the arch of the colon, three closely compacted together, rather high up on the left side, the fourth considerably lower, approaching the termination of the colon. The coats of the intestine were much thickened and formed into a sort of pouch, where the concretions lay. The peritoneum was but little inflamed, the other viscera were healthy. The concretion which lay by itself was sawed asunder by Mr. COULTATE, and contained a plum stone in the centre. The body was opened in the presence of the friends of the poor boy, and under circumstances which, unfortunately, prevented Mr. COULTATE from making so minute an examination as he could have wished, and from pressure of business and other unavoidable interruptions, he did not at

the time note down all the particulars of the case; but on referring to the prescriptions, he says that it does not appear that CHAMBERS ever took the smallest quantity of calcined magnesia or its carbonate, during the whole of his attendance. He had frequent doses of sulphate of magnesia, castor oil, and rhubarb; and during the latter period of his illness opium was often administered. CHAMBERS's usual diet was milk porridge twice a day, viz. at breakfast and supper; the milk thickened with oatmeal. His dinner commonly consisted of meat and potatoes; he rarely took any other kind of vegetable, and always ate oat cake at his dinner. In the afternoon he ate oat bread, and cheese, and drank beer; so that he never took a single repast without oatmeal in some shape or other. During his illness he occasionally had oatmeal gruel, and sometimes a little beef or mutton broth, into which it is usual in Lancashire to throw, whilst preparing it, a spoonful or two of oatmeal. He was also requested at this period, to live a good deal on milk and vegetables.

Mr. COULTATE adds, in his letter to Mr. THOMSON, that during the time he acted as assistant to Mr. BARLOW of Blackburn, a case similar to that of CHAMBERS's came under his care. The patient was a girl about fourteen years of age. The concretion had made its way down to the rectum, and was extracted by the forceps. It was about the size of a hen's egg, but appeared of a firmer texture, and felt heavier than those taken from CHAMBERS. The nucleus of this calculus was also a plum stone. The girl recovered; and Mr. COULTATE frequently saw her afterwards.

Another case also occurred in the course of Mr. BARLOW's practice in which eight similar concretions (the two largest

about the size of a hen's egg, the others much smaller) were extracted from the rectum of a boy in the neighbourhood of Blackburn. By the liberality of Messrs. COULTATE and BARLOW, the whole are now deposited in the Museum of the Royal College of Surgeons.

The concretions are of a light brown colour; the external coating is in parts firm and compact, and generally pretty smooth, and consists chiefly of a mixture of phosphate of lime and ammoniaco-magnesian phosphate. In other places the surface has a velvety feel and is composed of very fine fibres closely matted or felted together, and in some places these fibres are collected into considerable masses, as may be particularly seen in the cross section of the remaining half of the one selected for chemical examination. The husk of an oat was imbedded in the surface of the calculus which had been sawed asunder before I received it. Their general structure is laminated, and consists of concentric alternating layers of the fibrous substance and the phosphates. The external form of the concretions is various; three of them have assumed very solid figures, whilst the middle one of the three that were found lying together, is much flattened by the pressure of the outer ones. Their total weight, in the state in which I received them, was 2973½ grains, or about 4¼ ounces.

The largest weighed 1036 grains.
The smallest - - 511¼

They have all a very fetid disgusting smell. I found the specific gravity of the largest calculus at 60°, to be 1.875. At first it floated in distilled water with nearly a fourth of its bulk above the surface, but after the air which filled its pores had been extricated, by placing it immersed in water

under an exhausted receiver, it sunk readily in that fluid. The calculus selected by Sir EVERARD HOME for analysis, was divided by him, and the plum stone nucleus cut through as in the other. The unequal distribution of their component parts, renders it impossible that the results of any two analyses should agree very accurately in the relative proportions of the several ingredients of the concretions; there is no difficulty, however, in ascertaining their nature. They consist of phosphate of lime and ammoniaco-magnesian phosphate, the former in very much the largest proportion; of a large portion of animal matter, principally gelatine; a small portion of resin, and a fine fibrous vegetable substance, from the inner coat enveloping the farina of the oat, which, when the outer husk is removed, is seen to consist of a number of delicate fibres arranged longitudinally round the farina. I did not discover any fatty matter, either by the action of boiling water or a weak alkaline solution, nor any of the substances usually found in urinary calculi, except the phosphates already mentioned.

The method I adopted for the chemical examination of the calculus, was, by submitting it successively, (1) to the action of cold water; (2) of boiling water; (3) of alcohol; (4) of a dilute solution of caustic soda; and (5), of muriatic acid. The cold aqueous infusion exhibited no decided trace of albumen, either on being boiled, or by the test of corrosive sublimate. Sulphate of silver, muriate of baryta, and oxalate of ammonia rendered it slightly turbid. By the second and fourth processes I obtained animal matter, consisting chiefly of gelatine. Its solution in water passed very slowly through the filter whilst cold, more readily when hot. It was not

soluble in alcohol, gave no precipitate with solution of corrosive sublimate, but an abundant white one with infusion of galls. The solution by caustic soda (4), neutralized by weak acetic acid, gave also an abundant precipitate with infusion of galls, and none with corrosive sublimate. It was darker coloured than that obtained by water alone. In the third process, alcohol dissolved a small portion of resin, which water precipitated again perfectly white.

The muriatic acid dissolved the phosphates, and left the vegetable fibre.

To ascertain the relative quantities of the two phosphates, I destroyed the animal and vegetable matter of a fresh portion of the calculus by burning, dissolved the phosphates in muriatic acid, and precipitated them together by ammonia; I then digested the precipitate, whilst moist, in oxalic acid, filtered, and threw down the triple phosphate by ammonia, adding also a little phosphate of soda to secure the precipitation of the whole of the magnesia. The oxalate of lime was then decomposed by heat, its base re-dissolved in muriatic acid, and precipitated by sub-carbonate of ammonia, and the quantity of phosphate of lime inferred from that of the carbonate obtained. The proportions of the several ingredients of the calculus were as follows:

| | | |
|---|---|---|
| 2, 4 | Animal matter, chiefly gelatine | 25 . 20 |
| 3. | Resin - - - - | 3 . 90 |
| 5 | Ammoniaco-magnesian phosphate | 5 . 16 |
| | Phosphate of lime - - - | 43 . 34 |
| 6. | Vegetable fibre - - - | 20 . 80 |
| | | 99 . 90 |

I must not conclude this communication without referring to other similar alvine concretions, which have been at different times met with in those parts of the country where oatmeal is in common use as an article of food among the poorer classes. Dr. MARCET, in his Essay on Calculous Disorders, mentions a concretion which was showed to him by Dr. BOSTOCK, that had been voided by a labouring man in Lancashire; and Dr. MARCET himself examined another given him by Mr. SILVEIRA, who had it from Dr. MONRO of Edinburgh. It was in the examination of this calculus, that the true nature of the velvety fibrous substance was ascertained by Dr. WOLLASTON, who, Dr. MARCET says, "found it to consist of extremely minute vegetable fibres, or short needles, pointed at both ends; "which he immediately conjectured to arise from some kind "of food peculiar to Scotland. For some time, however, he "failed in his attempts to trace this substance to its origin. "But the ingenious Mr. CLIFT, of the College of Surgeons, "to whom the subject was mentioned in conversation, having "put the question, 'whether this fibrous substance might not "'proceed from oats,' Dr. WOLLASTON was induced to examine the structure of this seed; and the result fully "verified Mr. CLIFT's conjecture." (p. 139).

In Dr. ALEXANDER MUNRO's Morbid Anatomy of the Gullet, mention is made of forty-two alvine concretions collected by the Author's father, which were examined by Dr. THOMSON. Their structure, (with one exception similar in all) is described by Dr. MONRO (p. 32) "as more or less "porous, and somewhat like to dried sponge, and when examined by the aid of a magnifying glass, seems to be made "up of a number of very small fibres intimately interwoven

" with each other, like those in a hat, or in chamois leather; " and the interstices between the fibres are filled up with " earthy matter." And at p. 84 he adds, " in the centre of " the concretion, a *prune, or a cherry stone*, or a small piece of " bone, or a biliary calculus, is generally found."

Dr. THOMSON states the average specific gravity of these concretions to be 1.4. The one I weighed was, as mentioned above, considerably heavier. This may be owing to one containing more of the fibrous substance than the other, or to Dr. THOMSON not having employed an exhausted vessel to extricate the air from the pores of the calculus. Dr. THOMSON obtained from his analysis, albumen, common salts, phosphate of lime, phosphate of soda and the oat fibres, which he describes as " undoubtedly of a peculiar nature, dif- " fering from every animal and vegetable substance hitherto " examined." My results, in most respects, agree with Dr. THOMSON's, except that I could not discover any albumen; and on the other hand, the calculi examined by him, do not appear to have contained either the ammoniaco-magnesian phosphate or gelatine.

## IV. *On the concentric adjustment of a triple Object-glass.* By WILLIAM HYDE WOLLASTON, *M. D. V. P. R. S.*

Read December 13, 1821.

HAVING in my possession a telescope with a triple object-glass of forty-five inches focus, made by DOLLOND in 1771, I have had a good opportunity of examining the central adjustment of the lenses, and have made trial of a method of correcting that adjustment, which appears not to have been used for that purpose.

When I ventured to take to pieces an instrument that had stood the test of fifty years trial, with uniform approbation of its performance, those who knew the telescope, and who know the difficulty of centering, seemed to consider it an act of rashness which I was likely to regret; but, by the test which I am about to describe, I felt confident that my object-glass was capable of improvement, and I rested my hopes of success on principles that seemed indisputable.

When any bright object is viewed through a glass of this construction, without an eye-glass, there may be observed, at the same time with the refracted image, a series of fainter images, that are formed by two reflections from the different surfaces; and, as the position of each of these images is dependent on the curvatures of that pair of surfaces by which it is formed, they appear at different distances from the object-glass.

Since the number of surfaces is six, the number of binary

combinations of these surfaces is fifteen; and just so many images formed by reflection may be discerned.

It is manifest, that if the glasses be duly adjusted to each other, so that their axes are correctly coincident, then this series of images must be all situated in the same straight line; and conversely, that any defective position may be immediately detected by a derangement of the line of images.

A very distinct view of a part of these appearances, fig. 1. (Pl. I.) is seen by placing the eye close to the object end of the telescope, so as to view the eye-hole illuminated by the flame of a candle set near it. In this position only ten of them are perceived; two beyond the refracted image; four in regular succession nearer to the eye; and four very small ones close together, at a short distance from the object-glass within the tube.

The remaining five images being some inches exterior to the object-glass, cannot be seen till the eye is withdrawn to a greater distance, and are best observed with the assistance of a lens, fig. 2.

Each of the two first named images is formed by a pair of surfaces that are curved in the same direction, fig. 3, of which that which reflects from its concave side is most curved. The next four are also formed by surfaces that are curved in the same direction; but in this case, the convex reflecting surface is more curved than the concave, fig. 4. The four small images arise from pairs of surfaces, that have their convexities opposed to each other, fig. 5; and the five exterior images are owing to those pairs of surfaces which present their concave sides to each other.

In order to explain distinctly the origin of each of these

images, I have, in fig. 7, marked those surfaces which have their concavities toward the tube with large letters, A, B, C, and those curved in the opposite direction with the small letters, *d*, *e*, *f*; by which means, in fig. 8, where the origin of each image is indicated, similarity of source in the several groups will be seen from similarity of notation. The concurrence of a pair of large letters, or a pair of small letters, as BC, or *de*, shows combination of curvatures in the same direction as in figures 3 and 4; unequal letters in the order *d*C, show opposite curvatures, as of fig. 5, giving a negative focus; and the unequal letters, B*f*, in the opposite order, represent the opposite concavities of fig. 6, forming a positive focus beyond the glasses.

The origin of these images was ascertained by giving a small motion to one or the other of the convex glasses. When the outer glass is inclined, fig. 9, all the images dependent on A or *d* are inclined together in the same line *gh*; but it may be remarked, that the image A*d* is not displaced by this motion, as the relative position of the two surfaces A and *d* to each other remains unaltered.

In fig. 10, the inner glass is represented with a similar inclination; and with it all images dependent on C or *f* for their formation, assume an inclined position in the line *ik*.

By lateral motion of the outer glass, it is only the images dependent on A, that are moved; for since the motion takes place in the direction of the curve *d*, which remains in contact with the middle glass, the position of this surface is not altered, fig. 11.

By similar motion of the inner glass, fig. 12, those images only that are owing to *f* are moved, while those from C retain their position.

Any lateral motion given to the central concave has the same effect as moving both the convex glasses together in the opposite direction, and of course the effect is most discernible in the position of an image that is similarly affected by the lateral motion of both. For instance; downward motion of the concave, fig. 13, has the effect of placing a wedge between the two convex glasses from above, so that though each of their inner surfaces still remains in contact with the adjacent concave, their exterior surfaces, A and *f*, are parted from above, and the image A*f*, dependent on them both, is doubly elevated. Hence, the position of A*f* becomes a delicate test of the due centering of the concave glass, and is the best guide in making the final adjustment. In my object-glass, which has been the principal subject of my experiments, this image is very happily situated for this purpose, being so near to the outmost image, A*d*, that the smallest error in their relative position is with the greatest facility detected.

In order that I might have full command of each part, I had a cell constructed of larger dimensions than ordinary, with two pair of adjusting screws, at right angles to each other, applied to the edges of each glass, so that when the images had been first brought into the same vertical plane by means of one set of screws opposed to each other in the horizontal position, the series might next be adjusted to the same horizontal line by the screws placed above and below, at right angles to the former.

In performing these adjustments, there is another pair of images beside A*f*, A*d*, which deserve particular attention, as their motions are independent, and their contiguity renders any variation of their relative position very perceptible. In

figures 11 and 12, the lines *lm*, *no*, mark the irregularities arising from defects in centering of the inner and outer convex glasses, as in fig. 13, the line *pq*, shows the error correspondent to a want of adjustment of the middle concave.

By these guides alone I have now so repeatedly restored my object-glass to correct performance after having removed it from its cell, that I may venture, with considerable confidence, to recommend trial of the method to those who wish to perfect glasses of this construction. The degree of accuracy to be attained will depend upon the smallness and brightness of the light employed.

For the purpose of merely seeing the series of images above described, the entire flame of a candle, not confined by an eye-tube, forms a set of very conspicuous images. To see that the images are not very irregular, an eye-hole of one-fourth or one-fifth of an inch may be used. When the intention is to commence adjustment by candle-light, a single eye-glass of one-tenth or one-fifteenth of an inch focus will be found to give a series of neat images very well suited to the purpose; but, for completing a very nice adjustment, I have found it necessary to employ the light of the sun, and a still smaller lens of one-twentieth or one-thirtieth of an inch focus. With this view, there is no occasion to point the telescope to the sun, for if his light falls even very obliquely on a small eye-glass, the exterior images A*d*, and A*f*, are mere luminous points, so that any error in their relative position is immediately detected.

With this test, as guide for final adjustment, and without farther revision, the telescope on which this method has been tried, is capable of either separating very small and nearly

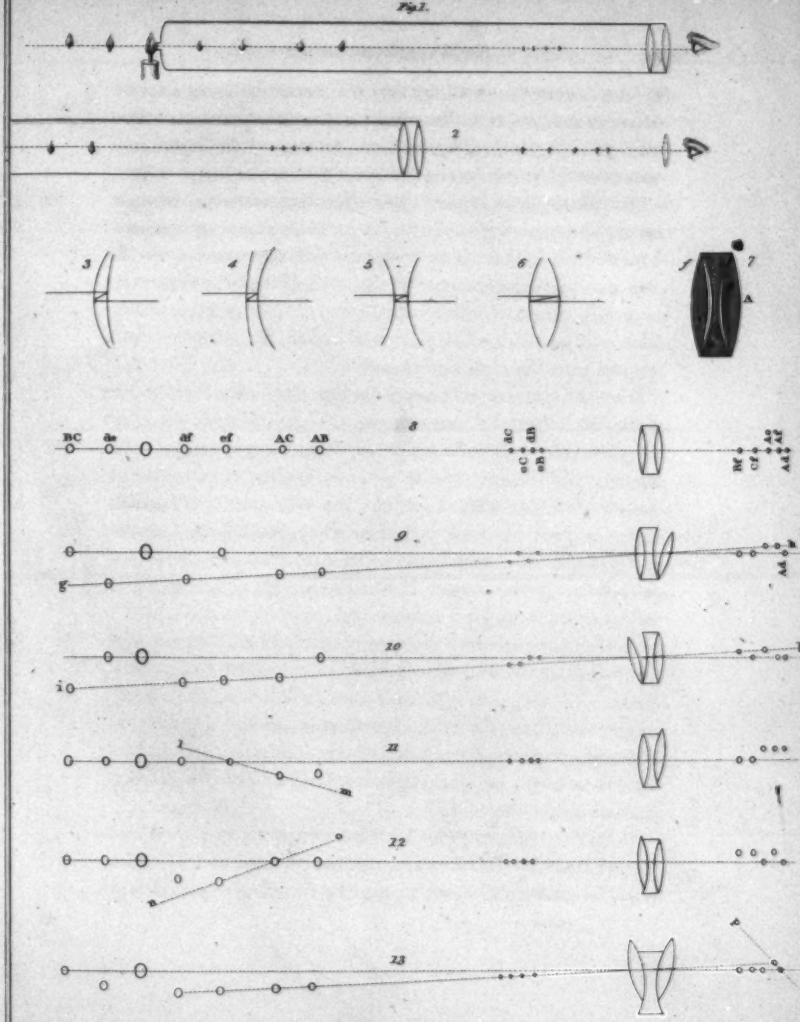
Fig. I.
2
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4
5
6
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A
8
BC
Bc
Bf
Ef
AC
AB
aC
aB
Af
Cf
Ac
9
g
h
10
i
k
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m
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n
13
o
p

equal stars as those of 44 Bootis and $\sigma$ Coronæ, or of exhibiting the minute secondaries of $\beta$ Orionis and $\alpha$ Aquilæ, with as much distinctness as the state of the air will admit. The actual limit to its powers cannot be fully ascertained, excepting under such favourable conditions of the atmosphere as do but rarely occur.

V. *On a new species of Rhinoceros found in the interior of Africa, the skull of which bears a close resemblance to that found in a fossil state in Siberia and other countries.* By Sir Everard Home, *Bart. V. P. R. S.*

Read December 13, 1821.

The discovery of a new species of any of the larger animals, now that our globe has been so extensively explored, is an object of interest to the naturalist, and might afford sufficient reason for laying this new fact before the Society; but this interest will be much increased, when there is a striking resemblance between the form and appearance of the skull of this animal, now in being, and the skull of one of the same tribe, only met with in a fossil state.

It has been hitherto asserted, as one of the most curious circumstances in the history of the earth, that all the bones that are found in a fossil state, differ from those belonging to animals now in existence; and I believe that this is generally admitted, and that there is no fact upon record, by which it has been absolutely contradicted; but the observations I am about to state respecting this rhinoceros, illustrated by the drawings that accompany them, will go a great way to stagger our belief upon this subject.

The skull of the animal belonging to this new species of rhinoceros, now living in Africa, was brought to this country by Mr. Campbell, one of the Missionaries sent there from

the London Missionary Society, and is deposited in their Museum in the Old Jewry. The following account is taken from the memoranda with which Mr. CAMPBELL very obligingly furnished me.

"The animal was shot about two hundred and fifty, or three hundred miles, up from the westward of De la Goa Bay, six miles west of the city Mashow, and above a thousand miles in nearly a straight direction from the Cape of Good Hope.

"The country from whence the rhinoceros comes, contains no thick woods, or forests, but is covered with separate clumps of trees, like a nobleman's park in England. In travelling, you always appear to be approaching a wood; but as you advance, the trees are discovered to stand at a distance from one another, or rather in little clumps.

"This animal feeds upon grass, and bushes; is not carnivorous; and not gregarious; seldom more than a pair are seen together, or in the vicinity of one another. Mr. CAMPBELL's people wounded another of the same description. When enraged it runs in a direct line, ploughing the ground with its horn. The hide is not welted, is of a dark brown colour, smooth, and without hair."

The skull which Mr. CAMPBELL has brought to England, fortunately has the horns in their natural situation. As the annexed drawing is made upon a scale, and the parts are so clearly exposed, it is hardly necessary to add a verbal description. It will be sufficient to say, that the skull is thirty-six inches long. The long horn, thirty-six inches; the circumference at the base, is twenty-four inches. There are horns

of different lengths in the British Museum, and one forty-two inches; a drawing of which is annexed.

In this skull it will be seen, that the horns differ in many particulars, from those belonging to the other recent species of the rhinoceros. The long one is placed upon the extremity of the nasal bones, with a direction nearly straight forward, and the smaller one so close behind it, as to appear intended for a support to its base. These striking differences would be of little importance, were it not that they make it bear so close a resemblance to the fossil skull from Siberia, as to leave no prominent characteristic mark between them; and were it not that the one is in a fossil state, and the other recent, they would be decided to belong to the same species; for although there is no horn attached to the fossil skull, the surface fitted for it is obviously marked, and no error can be committed, respecting its situation, or direction. The drawing is made from a fossil skull, sent over by the Emperor of Russia to Sir Joseph Banks, and deposited in the British Museum, and compared with another, which came to this country, but was afterwards sent to France. The skull is thirty-three inches long; the largest of the recent rhinoceros in the collection of the Royal College of Surgeons, is two feet.

The drawing of the skull from Siberia is so accurate, as to make a description of its external appearance unnecessary; it is however proper to add, that all the fossil skulls that have been examined, are alike, and three feet long; so that we have now acquired a nearer approach to the form of the skull of the rhinoceros of former ages, in that which is represented in these drawings, and is here described, than has before been obtained. From this fact, so completely

within my own observation, I am led to believe, that although many animals belonging to former ages may be extinct, they are not necessarily so; no change having taken place in our globe, which had destroyed all existing animals, and therefore many of them may be actually in being, although we have not been able to discover them.

When we consider that the course of one of the greatest rivers in Africa, the Niger, has not been traced to its source by any European traveller, we must allow, that great tracts of country in that immense continent remain unexplored; in which those animals, that are not disposed by their nature to submit to the will of man, but, on the contrary, to fly from him, may conceal themselves, by retiring into the wild fastnesses of forests, which for ages to come may never be visited by rational beings. Under these circumstances, we have no right to assume that large animals, although not met with, do not exist.

The following account of the migration of the animals in Africa, is in itself a curious document, and explains in what way particular animals may elude our enquiry at one time, and at another, be brought within our reach.

Mr. CAMPBELL says, "he found that the wild ass, or quagga, migrates in winter from the tropics, to the vicinity of the Malaleveen river, which, though farther to the south, is reported to be warmer than within the tropic of Capricorn, when the sun has retired to the northern hemisphere. He saw bands of two or three hundred, all travelling south, when on his return from the vicinity of the tropic; and various Bushmen, as he proceeded south, enquired if the quaggas were coming. Their stay lasts from two to three months,

which in that part of Africa is called the Bushmen's harvest. The lions who follow them are the chief butchers. During that season, the first thing a Bushman does on awaking, is to look to the heavens to discover vultures hovering at an immense height; under any of them he is sure to find a quagga that had been slain by a lion in the night."

This disposition for migration on large continents, will explain their dispersion into different countries.

It is deserving of remark that the elephant, one of the most powerful and most sagacious of the animal race, has been for ages domesticated (if the expression is admissible), and has learned to have a pride in the ornaments and trappings with which man, for the purpose of pomp and parade, has clothed him. It would appear that the sagacity of this noble animal had taught him, that to live in the bondage and society of men, is better than savage liberty; for when he has returned to a wild state, and remained in it for years, upon meeting with his former guide, immediately on hearing his voice he has returned to his duty. On the other hand, the rhinoceros, although an inhabitant of nearly the same countries, varying equally in species, and met with by men of different nations, in the same degree of frequency, has never been brought to a civilized state; but is at this day so savage and stupid in its nature, that it cannot be tamed.

The elephant, we know from observation, as well as from the size of its brain, particularly the cerebrum, has intellect and memory; but in the rhinoceros, so small is the cavity of the cranium, that in all these respects it must be much inferior to the elephant. The capacity of the cavity of the skull of the male rhinoceros from Sumatra, two feet long, is

to that of the elephant, as thirty-five ounces to one hundred and eighty-two. The length of the skull of the recent rhinoceros brought over by Mr. CAMPBELL, is three feet; and the cavity, although mutilated, shows it not to be larger than the other. In Mr. BROOKS's skeleton of the rhinoceros, five feet six inches high, the skull is only one foot eleven inches. His skeleton of the elephant is six feet six inches; so that Mr. CAMPBELL's rhinoceros must have been of the full size.

The skull of the horse has a capacity which, when compared with that of the rhinoceros, is to the small female of that species, nearly equal.

Skulls of the different species of rhinoceros known to exist, are preserved in the anatomical collections in this country, as well as in France. One species from Sumatra with two horns, one from Africa with two horns, and one with a single horn.

Of all these different species none have been found to possess a common share of intellect; the size of the cavity of the skull in all of them, is nearly the same; and there is no account upon record, of a rhinoceros ever having been tamed, although curiosity alone, would have been a sufficient inducement to have made the attempt, had there been any probability of success.

The following account, of the manners and habits of the Asiatic rhinoceros, clothed in armour, and having the welted hide, I have taken from the young man who was its keeper for three years in the Menagerie at Exeter Change, at the end of which period it died.

It was so savage, that about a month after it came to

Exeter Change, it endeavoured to kill the keeper, and nearly succeeded. It ran at him with the greatest impetuosity; but fortunately the horn passed between his thighs, and threw the keeper on its head: the horn came against a wooden partition, into which the animal had forced it to such a depth, as to be unable for a minute to withdraw it, and during this interval the man escaped.

Its skin, although apparently so hard, is only covered with small scales of the thickness of paper, with the appearance of tortoise shell; at the edges of these, the skin itself is exceedingly sensible, either to the bite of a fly, or the lash of a whip; and the only mode of managing it at all was by means of a short whip. By this discipline the keeper got the management of it, and the animal was brought to know him; but frequently, more especially in the middle of the night, fits of phrenzy came on, and while these lasted, nothing could controul its rage, the rhinoceros running with great swiftness round the den, playing all kinds of antics, making hideous noises, knocking every thing to pieces, disturbing the whole neighbourhood, then all at once becoming quiet. While the fit was on, even the keeper durst not make his approach. The animal fell upon its knees to enable the horn to bear upon any object. It was quick in all its motions: ate ravenously all kinds of vegetables, appearing to have no selection. They fed it on branches of the willow. It possessed little or no memory; dunged in one place, and if not prevented, ate the dung, or spread it over the sides of the wall. Three years confinement made no alteration in its habits.

The account in the Bible of an unicorn not to be tamed, mentioned by Job, bears so great an affinity to this animal,

W.m Clift del.t

S. Bairo sc.

Scale 3 inches to a Foot.

P. Th. Clift del.

F. Basire sc.

that there is much reason to believe that it is the same, more especially, as no other animal has ever been described so devoid of intellect. In that age, the short horn might readily be overlooked, as it cannot be considered as an offensive weapon; and the smoothness of the animal's skin would give it a greater resemblance to the horse than to any other animal.

## EXPLANATION OF THE PLATES.

### Plate II.

Fig. 1. A representation of the skull of the double-horned rhinoceros, brought from Africa by Mr. Campbell, and deposited in the Museum of the Missionary Society, in the Old Jewry: upon a scale of one inch and a half to a foot.

Fig. 2. A representation of the fossil horn of a rhinoceros, preserved in the British Museum: upon a scale of two inches to a foot.

### Plate III.

The representation (from a cast) of the fossil skull of the rhinoceros from Siberia, the original of which is in the collection of fossil bones in the Jardin des Plantes, in Paris: upon a scale of three inches to a foot.

## VI. *Extract of a Letter from Capt.* BASIL HALL, *R. N. F. R. S. to* WILLIAM HYDE WOLLASTON, *M. D. V. P. R. S, containing observations of a Comet seen at Valparaiso.*

Read January 10, 1822.

His Majesty's ship Conway,
Valparaiso, May 4, 1821.

MY DEAR SIR,

I HAVE much pleasure in sending you some observations which I have just made upon a comet that has been in sight here for 33 days. It is now almost gone, and I scarcely hope to get another satisfactory observation of its place. I was unfortunately in the interior of the country when it first appeared, so that it was not until the 8th of April that I was able to make any observation with accuracy. Since that day I have determined its place, as you will see, for several other days, and I trust there are data enough to work upon.

ever sincerely your's, &c. &c.

BASIL HALL.

## TABLE, showing the Places of the Comet seen at Valparaiso, in April and May 1821.

### Latitude 33° 2′ 18″.9 S°. Longitude 71° 36′ W.

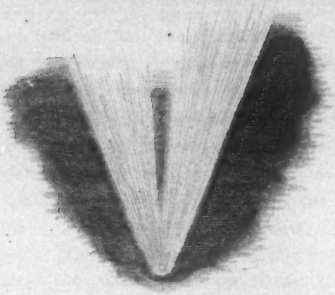
As observed by Capt. BASIL HALL, Lieut. WILLIAM ROBERTSON, and Mr. HENRY FOSTER, of His Majesty's Ship Conway.

| Date. | Mean Time. | R in Time. | Declination. (South.) | Stars with which the Comet was compared. (From Con. des Temps, 1819.) | Interval between the Passage of the Comet and the Star. (Sidereal Time.) | Difference of declination. (Comet S°, or N° of ✱.) | REMARKS. |
|---|---|---|---|---|---|---|---|
| 1821. | h. m. s. | h. m. s. | ° ′ ″ | | h. m. s. | ′ ″ | |
| Apr. 8 | 7.10.58 | 2.34.16 | 7.51.49 | 10 $\rho^1$ Eridani (4) | 21.14.5 | 26.26 N | Clear night. Land breeze, which gave the telescope a slight tremulous motion. |
| 11 | 6.54.45 | 2.46.29 | 7.12. 2 | 20 τ Orionis (4) | 1.22.26,8 | 9.20 S | Clear still night. Circumstances favourable. |
| 12 | 7. 2.30 | 2.50.14,6 | 6.58.39 | | 2.18.41,7 | 4. 3 N | Circumstances favourable. |
| 14 | 6.54.00 | 2.57.14,9 | 6.33.45 | 38 ο Eridani (4) | 1. 5.53,8 | 44.48,6 N | Comet very faint; but nucleus distinct in the telescope. Circumstances favourable. |
| 17 | 7.00.29 | 3. 6.43,1 | 5.58.11 | 17 Eridani (4,5) | 15. 1,9 | 16.34,9 S | Comet almost obliterated to the naked eye by the moon's light. The observations however are good this evening. |
| 18 | 6.36.52 | 3. 9.32,1 | 5.46.17 | ——— | 12.13,0 | 4.40,8 S | All circumstances favourable. |
| 19 | 6.34.54 | 3.12.26,0 | 5.34. 1 | ——— | 9.19,0 | 7.34,7 N | Comet very faint—weather hazy, with a fresh breeze, which gave a tremulous motion to the telescope. Circumstances not favourable. |
| 20 | 6.28.19 | 3.15. 8,0 | 5.23.58 | ——— | 6.37,1 | 17.38,3 N | All circumstances favourable, although the Comet appeared rather fainter than usual. |
| 21 | 6.30.10 | 3.17.46,4 | 5.13.32,7 | ——— | 3.58,6 | 28. 3,3 N | All circumstances very favourable. |
| 24 | 6.49.30 | 3.25.14,4 | 4.45.18,3 | 42 ξ Eridani (3,4) | 49.32,6 | 35.26,3 S | Circumstances all favourable. Comet very faint. |
| 29 | 6.48.36 | 3.36.29,2 | 3.57.46,8 | ——— | 38.17,8 | 12. 5,2 N | Circumstances all favourable, but Comet fainter. |
| May 1 | 6.31.40 | 3.40.15,8 | 3.41.15,9 | 48 ρ Eridani (4) | 47. 7,7 | 2.10,4 N | Circumstances very favourable. Comet very distinct. |
| 3 | 6.29.37 | 3.44.20,4 | 3.25.53,1 | ——— | 43. 3,1 | 17.33,2 N | Circumstances favourable—but the Comet very faint. This was the last observation made. |

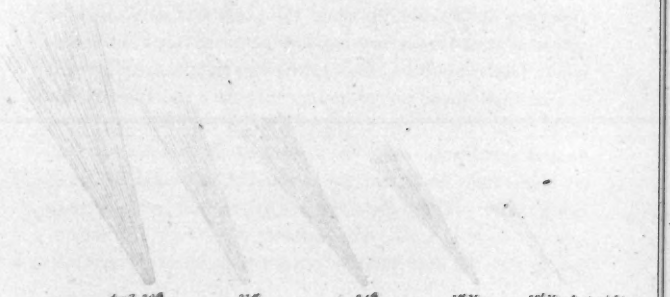
The foregoing right ascensions and declinations were determined by means of a wire micrometer attached to a power of about 80. The comet was always so near the horizon before it became visible, that on no evening during the whole month that it was observed, could its AR and declination be measured more than once. Unfortunately there were few known stars near the comet, so that it was often necessary to wait a considerable time before any one passed through the field of view. The high range of hills which encircle Valparaiso, also, interfered with these observations, as the comet became hid sooner than it otherwise might have been. During the first week the nucleus was very distinct, and might have been measured by the micrometer; but I was then in the interior of the country, and did not commence observing it till the 8th, when the nucleus had become so indistinct as to render any measurements of this kind uncertain. Lieutenant ROBERTSON of the Conway, assisted by Mr. FOSTER, midshipman of that ship, measured the angular distance of the comet from Aldebaran, Sirius, and Canopus, from its first appearance, until the splendour of the moonlight so far obliterated the comet, as to prevent any good distances being taken. These distances are given here, as they may serve to determine the comet's place, if required, for several days before the micrometrical observations were commenced.

| | | ° ′ ″ | | | ° ′ ″ | | | ° ′ ″ |
|---|---|---|---|---|---|---|---|---|
| 1st April 7 P. M. | Aldebaran | 44.42. 0 | 2d April 7 P. M. | | 43.24. 0 | 3d April 7.10 P.M. | | 42. 1.40 |
| | Sirius | 60.52.40 | | | 67. 8.30 | | | 65.28.40 |
| | Canopus | 68.10.50 | | | 67.18.40 | | | 66. 5.00 |
| | Barom. | 29.91 | | Barom. | 29.86 | | Barom. | 30. |
| | Ther. | 61. | | Ther. | 64 | | Ther. | 68 |
| 7th April 7.15 P.M. | Aldebaran | 37.35.22 | 8th April 7.5 P.M. | | 36.33.10 | 9th April 7.2 P.M. | | 35.35.30 |
| | Sirius | 60.46.48 | | | 59.45.25 | | | 58.49.40 |
| | Canopus | 64.11.17 | | | 63.45.27 | | | 63.20.40 |
| | Barom. | 29.97 | | Barom. | 29.86 | | Barom. | 29.94 |
| | Ther. | 60 | | Ther. | 60 | | Ther. | 62 |

(The error of the index has been applied to these distances.)



April 2nd



April 20th 21st 24th 1st May 3rd May last night seen

M.t Browne sc.

On its first appearance, the comet was of a dull white colour: the tail seemed to be split, or to have a dark streak between its sides. On the second evening, the tail subtended an angle of 7°, reaching to ρ Ceti: the northern part of the tail was the longest. On the third, the appearance was much the same. It was hid till the seventh by clouds: the tail then appeared shorter, and the nucleus less bright; changes which at the time were ascribed to the interference of the moon's light; but which, I think, must have arisen from the increased distance of the comet. The tail at first was nearly at right angles to the horizon, but at each succeeding night it inclined more to the south. The time of its appearance was always very short, and that time was generally occupied with the adjustment of the micrometer, so that I was not enabled to draw it so frequently as I could have wished; but these few sketches [Pl. IV.] will give some idea of its appearance.

BASIL HALL.

## VII. *Elements of Captain* HALL's *Comet. By* J. BRINKLEY, *D.D. F.R.S. and M.R.I.A. and Andrew's Professor of Astronomy in the University of Dublin. In a Letter addressed to* W. H. WOLLASTON, *M.D. V.P.R.S.*

Read, January 10, 1822.

Observatory, Trinity College, Dublin,
October 15, 1821.

MY DEAR SIR,

I SEND you the elements of the comet observed at Valparaiso, the observations of which you were so kind as to send to me.

We are indebted to the science of Captain HALL, for adding this comet to our catalogue.

The observations appear to have been as exact as could have been made even in an established observatory, on a comet only visible so near the horizon, and so far from the meridian, and of which the light was probably faint both from its actual distance from us, and its apparent proximity to the sun.

The comet on the 8th of April was distant nearly 1,41 from the earth, the sun's distance from the earth being unity, and on the 3d of May, when last seen, about 2,64.

This comet is interesting to astronomers on account of its small perihelion distance. In the Catalogue of M. DELAMBRE, out of 116 comets, the orbits of which have been computed, there are only three that pass nearer the sun.

It is interesting also, from the probability that it is the same comet that was observed in 1593, which agrees with this in

its small perihelion distance and great inclination. The inclination was computed by LACAILLE to be 88° nearly. The inclination of this is 106° 44′. The perihelion distance of that = ,089, of this ,093.

This comet would probably have been a very remarkable one by its appearance, had the earth been in a favourable situation.

It may, at first, cause some surprize, that it escaped the watchful observers of Europe when on the north side of the ecliptic, in February and March last, before it passed its perihelion; but on examination it will be found, that in March it was only a few degrees from the sun, and must have been rendered invisible by the superior lustre thereof. It passed from the north to the south side of the plane of the earth's orbit, March 21st, $18^h\ 30^m$, a few hours after it had passed its perihelion; and its elongation from the sun then was only about 4°.

The observations having been made so long after its passage through perihelion, the smallness of its perihelion distance, and some other circumstances, have involved the computation in difficulties not often met with. This induces me to request you will lay before the Royal Society, the method by which I proceeded.

The unusual circumstances relative to this comet, will also appear by referring to a passage in the Preface of M. BURCKHARDT's new table of the Parabolic Movements, &c. in the Conn. des Temps, 1818. It relates to the interval of his table from 1000 to 10,000 days, of which he says, "comme il est probable que cette partie ne servira *jamais* dans la pratique, &c." Now, in the observations after the 18th of April,

the anomalies of this comet exceeded that of 1000 days in the tabular comet.

Besides the elements (B) deduced by the method of which the explanation is given, I had previously deduced another set (A) by a process less certain in its operations. The latter set (A) however, may be thought not much inferior to the other set (B).

I remain, my dear Sir,

your's most truly,

*Dr. Wollaston, &c. &c. &c.* J. BRINKLEY.

Elements (B.)

Perihelion distance ,092800
Time of passage through perihelion
Mean Time, Greenwich, March 21st. — h. m. s. 13 15 47

| | | ° | ′ | ″ |
|---|---|---|---|---|
| Inclination | s. | 73 | 15 | 48 |
| Node (ascending) | | 1 | 18 | 24 41 |
| Perihelion | | 7 | 29 | 6 47 |

Motion retrograde.

Elements (A.)

Perihelion distance ,0894
Passage through perihelion March 21, — h. m. s. 7 3 26

| | | ° | ′ | ″ |
|---|---|---|---|---|
| Inclination | s. | 74 | 32 | 41 |
| Node | 1 | 19 | 38 | 17 |
| Perihelion | 8 | 0 | 35 | 8 |

Motion retrograde.

| 1821. | Observation. Mean Time Valparaiso. | Observation. Longitude. | Observation. Latitude S. | Error of Elements (B.) Long. | Error of Elements (B.) Lat. | Error of Elements (A.) Long. | Error of Elements (A.) Lat. |
|---|---|---|---|---|---|---|---|
| | h. m. s. | ° ′ ″ | ° ′ ″ | ′ ″ | ° ″ | ′ ″ | ′ ″ |
| April 8 | 7 10 58 | 33 27 44,3 | 21 48 8,0 | 0 0 | 0 0 | +0 20 | 0 0 |
| 11 | 6 54 45 | 36 47 3,4 | 22 10 15,2 | +1 28 | +0 29 | +0 53 | +0 2 |
| 12 | 7 2 30 | 37 49 5 | 22 15 26 | +1 11 | +0 45 | +0 26 | +0 13 |
| 14 | 6 54 0 | 39 44 25,9 | 22 24 26,2 | +0 56 | +0 7 | +0 1 | —0 29 |
| 17 | 7 0 29 | 42 21 57 | 22 33 9 | +0 56 | —0 30 | 0 0 | —1 7 |
| 18 | 6 36 52 | 43 9 14 | 22 34 7 | +1 36 | +0 17 | +0 45 | —0 18 |
| 19 | 6 34 54 | 43 57 55 | 22 34 55 | +0 1 | +0 56 | —0 46 | +0 24 |
| 20 | 6 28 19 | 44 42 53 | 22 36 50 | +0 25 | +0 9 | —0 14 | —0 21 |
| 21 | 6 30 10 | 45 26 57,0 | 22 37 58,8 | +0 36 | —0 8 | +0 4 | —0 34 |
| 24 | 6 49 30 | 47 31 42,7 | 22 41 31,3 | +1 11 | —2 15 | +1 6 | —2 32 |
| 29 | 6 48 36 | 50 41 8,7 | 22 39 37,2 | —2 4 | —0 38 | —1 16 | —0 41 |
| May 1 | 6 31 40 | 51 44 55,1 | 22 37 45,6 | +2 4 | +0 51 | +3 13 | +0 49 |
| 3 | 6 29 37 | 52 52 55,1 | 22 37 42,7 | —0 50 | +0 15 | +0 45 | +0 22 |

*Computation of the Elements.*

The method used for the first approximation was that of M. LAPLACE.* The observations chosen were those of April 8, 11, and 14. It considerably diminishes the length of the calculation to use only three observations, where it can be done. In the present instance it is not likely, had a greater number of observations been used, that the superior accuracy derived would have compensated for the additional trouble. The result from the three observations, is as exact as would be necessary on common occasions. Here, on account of the small perihelion distance and small motion of the comet in heliocentric longitude between the first and last observations, the method of M. LAPLACE,† " Determination exacte des elemens de l'orbite, &c. &c." is inapplicable; the errors of the motion in heliocentric longitude being greater than the motion itself.

The extension however of that method, as indicated by M. DELAMBRE,‡ might succeed in this instance, but the formidable calculations necessary are sufficient to deter one from the attempt.

The method which I gave in Vol. XIII. p. 189, of the Transactions of the Royal Irish Academy, also, in this case, requires to be extended. It will be necessary to introduce the squares of the variation of the perihelion distance, and of the correction of the time from perihelion.

The manner in which my method is extended to this case will be easily understood from the following detail; and also the change I have made in deriving on common

* Mec. Celes. Tom. i. p. 221, &c. † p. 225. ‡ Astron. Tom. 3. p. 384.

occasions the final equations, by using a formula for the computation of V, different from that given by M. LAPLACE.

Previously to the computation, I re-calculated the observations of April 8, 11, 14, 21, and May 3, using the places of the stars as given by M. PIAZZI. This perhaps was unnecessary.

The results were

| | | AR | Declination S. |
|---|---|---|---|
| | | h. m. s. | ° ′ ″ |
| April | 8 | 2 34 15,0 | 7 51 52 |
| | 11 | 2 46 28,0 | 7 12 4 |
| | 14 | 2 57 14,2 | 6 33 51 |
| | 21 | 3 17 46,1 | 5 13 35 |
| May | 3 | 3 44 19,7 | 3 25 55 |

By M. LAPLACE's method, "Determination approchée, &c." the observations of April 8, 11, and 14, give perihelion dist. $(p) = ,c865$, and time of perihelion, March $19^d\ 14^h\ 4^m$.

Let the true perihelion dist. $= p + dp$, and time of perihelion $=$ March $19^d\ 14^h\ 4^m - dt$, so that $t$ being the interval between March $19^d\ 14^h\ 4^m$, and the observation of April 8, the true value of $t = t + dt$.

Let also T $=$ the time in the table of the comet of 109 days, when the anomaly $= \nu$.

$\Delta =$ variation of anomaly in that table in one day at time T, and $r =$ comet's distance from the sun

$$\text{Then } d\nu = \left(\frac{dt}{p^{\frac{1}{2}}} - \frac{3tdp}{p^{\frac{3}{2}}}\right)\Delta \quad - \quad - \quad (1)$$

$$\text{and } (x)\ \frac{d\log r}{\sin 1''} = d\nu \tan \tfrac{1}{2}\nu + \frac{dp}{p \sin 1''} \quad (2)$$

Conceive the triangle in which S, T, C, represent the sun, earth, and comet respectively, and let P represent the projection of the comet on the plane of the earth's orbit.

In this case, comet's hel. long.=earth's long.—TSP. Also

$d$ hel. lat. $(\pi) = x \tan \text{SCT} \cot \text{CST} \tan \pi$. - - - (3)

$d$ hel. long. $(\beta) = -x \cot \text{TSP} \tan \text{SCT} (\tan \text{CST} - \cot \text{CST} \tan^2 \pi) - (4)$

These angles SCT, &c. are found in the course of the calculation.

If $\beta$, $\beta'$ $\beta''$ represent three hel. longitudes, and $\pi$, $\pi'$ $\pi''$ represent three hel. latitudes, and V, V′ represent the bases of two spherical triangles of which the sides are $90°-\pi$, $90°-\pi'$, and $90°-\pi$, $90-\pi''$, and the vertical angles $\beta-\beta'$ and $\beta-\beta''$ respectively,

$$\cos V = \cos(\pi-\pi') - 2\sin^2\tfrac{1}{2}(\beta-\beta')\cos\pi'\cos\pi \quad (5)$$

$$\cos V = \cos(\pi-\pi'') - 2\sin^2\tfrac{1}{2}(\beta-\beta'')\cos\pi''\cos\pi \quad (6)$$

Taking the observations of April 8, 21, and May 3, and the above values of $p$ and $t$,

| | Anomalies. | Hel. Long. | Hel. Lat. S. |
|---|---|---|---|
| | ° ′ ″ | S. ° ′ ″ | ° ′ ″ |
| April 8 | 139 46 38*=$\nu$ | 2 5 17 1=$\beta$ | 48 55 19=$\pi$ |
| 21 | 146 38 6 =$\nu'$ | 2 3 47 40=$\beta'$ | 42 43 42=$\pi'$ |
| May 3 | 150 12 10 =$\nu''$ | 2 2 35 30=$\beta''$ | 39 22 50=$\pi''$ |

If $U=\nu'-\nu$ and $U'=\nu''-\nu$

The observations of April 8 and April 21, give

$$U = 6° 51' 28'' \quad V = 6° 16' 44''$$

Those of April 8, and May 3, give

$$U' = 10° 25' 32'' \quad V' = 9° 44' 19''$$

Therefore because $U + dU = V + dV$

and $U' + dU' = V' + dV'$

* The results are put down to seconds; but as only five places in the logarithms were used in this part of the process, they may sometimes err by several seconds.

$$dV - dU = 2084'' \quad - \quad - \quad (8)$$

$$dV' - dU = 2480'' \quad - \quad - \quad (9)$$

By the formulæ above given

$$d\nu = 2751\ dt - 950080\ dp$$
$$d\nu' = 1336\ dt - 762080\ dp$$
$$d\nu'' = 861\ dt - 669980\ dp$$
$$x = 7512\ dt - 209300\ dp$$
$$x' = 4459\ dt - 158300\ dp$$
$$x'' = 3235\ dt - 133450\ dp$$
$$d\pi = -,4890\ x \quad .. \quad d\beta = -,9345\ x$$
$$d\pi' = -,3446\ x' \quad .. \quad d\beta' = -,4867\ x'$$
$$d\pi'' = -,2954\ x'' \quad .. \quad d\beta'' = -,2130\ x''$$

From these values it is necessary to compute $dV$, $dV'$.

Let $H = 2 \sin^2 \frac{1}{2} (\beta - \beta') \cos \pi' \cos \pi$

$H = 2 \sin^2 \frac{1}{2} (\beta - \beta'') \cos \pi'' \cos \pi$

then equations (5) and (6) become

$$\cos V = \cos (\pi - \pi') - H \quad - \quad (10)$$

$$\cos V' = \cos (\pi - \pi'') - H' \quad - \quad (11)$$

It is obvious from the smallness of $\beta - \beta'$ and $\beta - \beta''$, and the magnitude of the errors of U—V and U′—V″ that the errors of $\beta - \beta'$ and $\beta - \beta''$ may bear a considerable proportion to the quantities themselves, or be even greater. Therefore the coefficients of the differentials $dp$ and $dt$ in $dH$ will be quite incorrect, if the differential of H be computed in the common way.

It is the smallness of $\beta - \beta'$ and $\beta' - \beta''$ in this case that renders M. LAPLACE's method of computing V, V′ inconvenient, in consequence of its being necessary to use the tangent of an angle nearly $= 90°$.

But the variations of V and V′ may be obtained with sufficient accuracy in the following manner.

By equation (10) we easily deduce an account of the smallness of H

$$V = \pi - \pi' + \frac{H}{\sin 1'' \sin (\pi - \pi')}$$

and with sufficient exactness

$$V + dV = \pi - \pi' + d\pi - d\pi' + \frac{2 \sin 1'' \cos \pi' \cos \pi (\beta + d\beta - \beta' - d\beta')}{\sin (\pi - \pi')}$$

therefore

$$dV = -(d\pi - d\pi') + \pi - \pi' - V + \frac{2 \sin 1'' \cos \pi' \cos \pi (\beta + d\beta - \beta' - d\beta')}{\sin (\pi - \pi')}$$

and the same expression serves for $dV'$ changing $\pi'$, $\beta'$ and V into $\pi''$, $\beta''$ and V'.

Hence, substituting the values of $\beta, \beta', \beta'', \pi', \pi'', \pi'''$ &c. &c. we obtain

$$dV = -344'' + ,3446x' - 4390x + N(2680 - ,4672x + ,2188x')$$
$$dV' = -703 + ,2954x'' - 4390x + N'(4845 - ,4672x + ,1065x'')$$

where log N = 5.63801 and log N' = 5.47828

and finally, equations (8) and (9) give

$$N(2680 - 2534dt + 63150dp) - 364dt - 150649dp = 2428 \quad (12)$$
$$N'(4845 - 3166dt + 83572dp) - 452dt - 227619dp = 3212 \quad (13)$$

From these equations the values of $dp$ and $dt$ may be derived. The indirect solution seems to be the shortest, as we know the value of $dp$ within narrow limits.

The first error of $p$ as deduced from the approximation of LAPLACE, rarely indeed will amount to $\pm$ ,01.

1. Let us suppose $dp = -$ ,005. Then equation (12) gives $dt = +4,294$ and $-1,194$. The positive value is too great to be admitted, taking $t = -1,194$, the result from equation (13) is $0 = -468$.

* This number $344'' = 6^\circ\ 16'\ 44'' - 6^\circ\ 11'\ 37''$; but the accidental omission of $37''$ is not of the smallest consequence in the result.

2. $dp = ,000$
$dt = +4,901$ and $-1,547$, substituting in equation (18)
$t = -1,547$
$0 = -309$

3. $dp = +,005$
$dt = +5,442$ and $-1,838$
$0 = -137$

the value of $dp$ therefore exceeds $+,005$.

The last result shows, that with this value of $dp$, the errors of V — U and V′ — U′ are reduced to comparatively small quantities, and it may be useless in this first process to endeavour to reduce them still more.

Therefore we may now make $p = ,0865 + ,005 = ,0915$, and $t = 19,9118 - 1,838 = 18,0738$.

With these values we obtain, having corrected the sun's places and comet's observed places for aberration, and made the computations to seven places of figures,

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| April | 8 | 136 | 53 | 51 | = ϑ | 2 | 9 | 47 | 31 | = β | 50 | 51 | 16 | = α |
| | 21 | 144 | 50 | 48 | = ϑ′ | 2 | 4 | 59 | 14 | = β′ | 43 | 38 | 4 | = α′ |
| May | 3 | 148 | 48 | 45 | = ϑ″ | 2 | 3 | 12 | 5 | = β″ | 39 | 56 | 29 | = α″ |

V = 7° 55′ 6″, V′ = 11° 55′ 38″

On account of the great changes that have taken place in some of these quantities, particularly in the longitudes; it will be better to re-compute $d\vartheta$, $d\pi$, $d\beta$, &c. &c.

This in common cases would be unnecessary.

The new values are

$$d\lambda = 3299\,dt - 977400\,dp$$
$$d\lambda' = 1510\,dt - 768685\,dp$$
$$d\lambda'' = 947\,dt - 667980\,dp$$
$$x = 8353\,dt - 220500\,dp$$
$$x' = 4768\,dt - 172700\,dp$$
$$x'' = 3390\,dt - 138150\,dp$$
$$d\pi = -,4543x \quad d\beta = -1,1486\,x$$
$$d\pi' = +,3599x' \quad d\beta' = -,4756\,x'$$
$$d\pi'' = -,3053x'' \quad d\beta'' = -,2252\,x''$$

We may now use the equations (10) and (11) for finding $dV$ and $dV'$

$$dV \sin V = \sin(\pi - \pi')\,(d\pi - d\pi') + \frac{dH}{\sin 1''}$$
$$dH = H \sin 1''\,(\tan\tfrac{1}{2}(\beta - \beta')\,(d\beta - d\beta') - d\pi' \tan\pi' - d\pi \tan\pi)$$

The expressions for $dV'$ and $dH'$ are had by changing H, $\beta'$ and $\pi'$ into H', $\beta''$ and $\pi''$.

Then, by substituting the above values for $d\pi$, $d\pi''$, &c. &c.

$$dV = -3858\,dt + 80110\,dp$$
$$dV' = -4888\,dt + 112190\,dp$$

and the equations

$$U + dU = V + dV$$
$$U' + dU' = V' + dV$$

become

$$-2069\,dt - 128650\,dp = 111 \qquad (14)$$
$$-2586\,dt - 197280\,dp = 80 \qquad (15)$$

which give

$$dp = +,001425 \text{ and } dt = -,1493$$

Consequently, the new approximate values of $p$ and $t$ are

$$p = ,092925 \text{ and } t = 17,9315$$

Repeating the computation with these values we obtain

| | | | |
|---|---|---|---|
| April 8 | 136 22 43 = ☽ | 2 10 16 43 = β | 51 2 44 = π |
| 21 | 144 28 59 = ☽′ | 2 5 6 34 = β′ | 43 43 35 = π′ |
| May 3 | 148 30 40 = ☽″ | 2 3 3 35 = β″ | 39 59 56 = π″ |

$$V = 8^\circ\ 6'\ 29 \qquad V' = 12^\circ\ 8'\ 7''$$

and thence $U - V = -18''$ and $U' - V' = -11$

Substituting these values on the right hand side of equations (14) and (15), and solving the equations

$$dp = -,0001249 \text{ and } dt = ,014049$$

and the new values of $p$ and $t$ are $p = ,092800$, and $t = 17,9456$, which are sufficiently exact. From these new values of $dp$ and $dt$ we very easily get from the above values of $d_1$ &c. &c.

| | | | |
|---|---|---|---|
| April 8 | 136 25 33 = ☽ | 2 10 13 57 = β | 51 1 39 = π |
| 21 | 144 30 56 = ☽′ | 2 5 5 52 = β′ | 43 43 3 = π′ |
| May 3 | 148 32 16 = ☽″ | 2 3 3 20 = β″ | 39 59 36 = π″ |

$$V = 8^\circ\ 5'\ 24'' \qquad V' = 12^\circ\ 6'\ 45''$$

The differences between the first values of $\beta$, $\beta'$ &c. &c. and these correct values, seem deserving of notice.

It remains to find the place of the node, inclination of the orbit, and the place of perihelion.

For this purpose it is very convenient and sufficiently exact* to compute, in the spherical triangle formed by the sides

* We are enabled to use this short process for finding the inclination, in consequence of being able to compute so readily the new values of $dV$, and $dV$ as well as of $d\pi$, $d\beta$, &c. &c. by substituting in the values above given, the last values of $dp$, $dt$. This may be considered as another advantage of this method of correcting the approximate elements of a comet's orbit.

$90-\pi$, $90-\pi''$ and V', the angle opposite to $90-\pi''$, and also in the spherical triangle formed by $90-\pi$, $90-\pi'$ and V, the angle opposite to $90-\pi'$.

These angles are

152° 38′ 9″, which gives the inclination 78° 19′ 50″.

152 51 56, which gives the inclination 78 11 47

Now, if the orbit were an exact parabola, and the observations perfectly accurate, the above quantities ought, in consequence of the exactness that has been used in the computation, to agree to a second. Hence is seen the unavoidable errors arising from these two causes jointly. It is probable, that the deviation from a parabola has no sensible effect in the present case.

With the mean value 152° 45′ 8″ we get the place of the node 48° 24′ 41″, and the place of perihelion $=7^s$ 29° 6′ 47″.

There evidently appears an irregularity in the three last right ascensions observed April 29, May 1 and 3. It is possible, that this happened in consequence of the difficulty of observing the comet from its faintness: if so, each of the observations may partake of that irregularity, and the inaccuracy of the observation of May 3, may have affected the elements.

This might have been avoided, by combining a greater number of observations in correcting the approximate elements, but the advantage would not, probably, have repaid the additional labour.

The remark on these latter observations, must not be understood to imply, in the smallest degree, a defect in observing; on the contrary, the general exactness of the observations appears highly creditable to the observers, and requires no

allowance for the unavoidable difficulties under which they must have observed.

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Note.—The computations relative to the comet observed by Captain HALL, were finished in the middle of October last, and the results immediately sent to London for the purpose of being laid before the Royal Society. The second part of the Transactions for 1821, did not reach me till after the communication had been read at the Royal Society. In that second part, I was much surprised to find the elements of the same comet computed by Mr. RUMKER, from the observations made by Dr. OLBERS, before the passage through perihelion.

Subsequently, the "Conn. des Tems," for 1824 reached me, which contains Observations made at Paris, and Elements by M. NICOLLET; also a notice of the comet having been observed in several places of Europe. It certainly is highly creditable to those observers who discovered, under very difficult circumstances, the comet in its approach to the sun.

By the addition of Captain HALL's observations after the passage through perihelion, we are enabled to obtain very exact elements.

The errors of my Elements, when applied to observations before perihelion, and the errors of Mr. RUMKER's and of M. NICOLLET's Elements, when applied to Captain HALL's observations after perihelion, are considerable:

Therefore, I have farther corrected my Elements, by using Dr. OLBERS' observations of January 30, with those of Captain HALL of April 8, and May 8.

The new elements (C) are

Perihelion distance ,091677

| | | | |
|---|---|---|---|
| Time of passage through perihelion | March 21, | h. m. s. 11 11 48 | Mean time Greenwich. |
| Inclination | | 78 34 53 | |
| Node | | 48 42 18 | |
| Place of perihelion | | 239 30 33 | |

Motion retrograde.

Errors of the Elements (C).

| | Error in Longitude. | Error in Latitude. | Observers. |
|---|---|---|---|
| | ″ | ″ | |
| Jan. 21 | + 0 18 | — 0 12 | M. NICOLLET, Paris. |
| 30 | + 1 6 | + 0 13 | Dr. OLBERS, Bremen. |
| Feb. 9 | — 0 28 | — 0 44 | M. NICOLLET. |
| Mar. 6 | — 2 17 | — 0 57 | Dr. OLBERS. |
| April 8 | + 0 18 | — 0 45 | Captain HALL, Valparaiso. |
| 20 | + 0 11 | — 0 30 | Ditto. |
| May 3 | — 0 49 | + 0 12 | Ditto. |

Between January 21, and May 8, the comet described above 300° about the sun: consequently, as a parabola represents the observations with so much exactness, it follows, that the period of its revolution must be considerable.

J. B.

Observatory, Trinity College, Dublin,
Feb. 25, 1822.

## VIII. *On the Electrical phenomena exhibited in vacuo.* By Sir Humphry Davy, *Bart. P. R. S.*

Read December 20, 1821.

The production of heat and light by electrical discharges: the manner in which chemical attractions are produced, destroyed, or modified by changes in the electrical states of bodies: and the late important discovery of the connection of magnetism with electricity, have opened an extensive field of enquiry in physical science, and have rendered investigations concerning the nature of electricity and the laws by which it is governed, and the properties that it communicates to bodies, much more interesting than at any former period of the history of philosophy.

Is electricity a subtile elastic fluid? or are electrical effects merely the exhibition of the attractive powers of the particles of bodies? Are heat and light elements of electricity, or merely the effects of its action? Is magnetism identical with electricity, or an independent agent, put into motion or activity by electricity?—Queries of this kind might be considerably multiplied, and stated in more precise and various forms: the solution of them, it must be allowed, is of the highest importance; and though some persons have undertaken to answer them in the most positive manner, yet there are, I believe, few sagacious reasoners, who think that our present data are sufficient to enable us to decide on such very abstruse and difficult parts of corpuscular philosophy.

It appeared to me an object of considerable moment, and one intimately connected with all these queries, *the relations of electricity to space, as nearly void of matter as it can be made on the surface of the earth*; and, in consequence, I undertook some experiments on the subject.

It is well known to the Fellows of this Society who have considered the subject of electricity, that Mr. WALSH believed that the electrical light was not producible in a perfect torricellian vacuum; and that Mr. MORGAN drew the same inference from his researches; and likewise concluded that such a vacuum prevented the charging of coated glass.—Now it is well known, that in the most perfect vacuum that can be made in the torricellian tube, vapour of mercury, though of extremely small density, exists; I could not help, therefore, entertaining a doubt as to the perfect accuracy of these results, and I resolved not only to examine them experimentally, but likewise, by using a comparatively fixed metal in fusion for making the vacuum, to exclude, as far as was possible, the presence of any volatile matter.

The apparatus that I employed was extremely simple, [Pl. V.] and consisted of a curved glass tube with one leg closed, and longer than the other. In this closed leg a wire of platinum was hermetically cemented, for the purpose of transmitting the electricity: or to ascertain the power of the vacuum to receive a charge, it was coated with foil of tin or platinum. The open end, when the closed leg had been filled with mercury or any other metal, was exhausted either by being placed under the receiver, or connected with the stop-cock of an excellent air pump; and in some cases, to ensure

greater accuracy, the exhaustion was made after the tube and apparatus had been filled with hydrogene.*

Operating in this way, it was easy to procure a vacuum either of a large or small size, for the rarefied air or gas could be made to balance a column of fluid metal of any length, from 20 inches to the 20th of an inch, and by using only a small quantity of metal, it could be more easily purged of air.

I shall first mention the results I obtained with quicksilver. I found that by using recently distilled quicksilver in the tubes, and boiling it in vacuo six or seven times from the top to the bottom, and from the bottom to the top, making it vibrate repeatedly by striking it with a small piece of wood, a column was obtained in the tube free from the smallest particle of air; but a phenomenon occurred, in discovering the cause of which I had a great deal of trouble. When I used a short tube of four or five inches long only, I found, that after continued boiling and much agitation of the mercury, though there was no appearance of elastic matter, when the mercury adhered strongly in the upper part of the tube, yet that, after electrization, or even on suffering the mercury to pass slowly back into the closed part, a minute globular space sometimes appeared: I thought at first that this was air, which, though so highly rarefied, as it must have been by the exhaustion, adhered to the mercury; and I endeavoured by long boiling the mercury in an exhausted *double* syphon, and making the vacuum in one of the curves, to prevent entirely the presence of air: but the phenomenon always occurred when there was no strong adhesion of the mercury

* The figure will best explain the form of the apparatus.

to the glass. This, and another circumstance, namely, that when the leg in which the torricellian vacuum was made was 15 or 16 inches long, the phenomenon was very rarely perceptible, and always disappeared when the tube was inverted, and the mercury made to strike the top with some force, led me to conclude that the minute space was really filled with the vapour of mercury; the attraction of the particles of the fluid mercury for each other preventing their actual contact with the glass, except when this contact was forcibly made by mechanical means; and I soon proved that this was the case: for by causing the mercury, when its column was short, to descend into the more perfect from the less perfect vacuum, with more or less velocity, I could make the space more or less, or cause its disappearance altogether, in which last case the cohesion between the mercury and the glass was always extremely strong.

I found that in all cases when the mercurial vacuum was perfect, it was permeable to electricity, and was rendered luminous by either the common spark, or the shock from a Leyden jar, and the coated glass surrounding it became charged; but the degree of intensity of these phenomena depended upon the temperature: when the tube was very hot, the electric light appeared in the vapour of a bright green colour, and of great density; as the temperature diminished, it lost its vividness; and when it was artificially cooled to 20° below zero of FAHRENHEIT, it was so faint as to require considerable darkness to be perceptible.

The charge likewise communicated to the tin or platinum foil was higher the higher the temperature; which, like the other phenomenon, must depend upon the different density of

the vapour of mercury; and at 0° FAHRENHEIT it was very feeble indeed.

A very beautiful phenomenon occurred in boiling the mercury in the exhausted tube, which showed the great brilliancy of the electrical light in pure dense vapour of mercury. In the formation and condensation of the globules of mercurial vapour, the electricity produced by the friction of the mercury against the glass, was discharged through the vapour with sparks so bright as to be visible in day light.

In all cases when the minutest quantity of rare air was introduced into the mercurial vacuum, the colour of the light produced by the passage of the electricity changed from green to sea green; and, by increasing the quantity, to blue and purple; and when the temperature was low, the vacuum became a much better conductor.

I tried to get rid of a portion of the mercurial vapour, by using a difficultly fusible amalgam of mercury and tin, which was made to crystallize by cooling in the tube; but the results were precisely the same as when pure mercury was used.

I tried to make a vacuum above the fusible alloy of bismuth; but I found it so liable to oxidate and dirt the tube, that I soon renounced farther attempts of this kind.

On a vacuum above fused tin I made a number of experiments; and by using freshly cut pieces of grain tin, and fusing them in a tube made void after being filled with hydrogene, and by long continued heat and agitation, I had a column of fused tin which appeared entirely free from gas: yet the vacuum made above this, exhibited the same phenomena as the mercurial vacuum. At temperatures below 0°, the light was yellow, and of the palest phosphorescent kind,

requiring almost absolute darkness to be perceived; and it was not perceptibly increased by heat.

I made two experiments on electrical and magnetic repulsions and attractions in the mercurial vacuum, by attaching to the platinum wire two fine wires in one case of platinum, in the other of steel, terminated by minute spherules of the same metals: I found that they repelled each other when the wire was electrified in the most perfect mercurial vacuum, as they would have done in usual cases; and the steel globules were as obedient to the magnet as in the air; which last result it was easy to anticipate.

In some of the first of these experiments, I used a wire for connecting the metal with the stop-cock; but latterly, the rarefied air or gas was the only chain of communication; and this circumstance enabled me to ascertain that the feebleness of the light in the more perfect vacuum was not owing merely to a smaller quantity of electricity passing through it, for the same discharge which produced a faint green light in the upper part of the tube, produced a bright purple light in the lower part, and a strong spark in the atmosphere.

The boiling point of pure olive oil is not much below that of mercury; and the butter or chloride of antimony (antimonane) boils at about 388° Fahrenheit. I tried both these substances in the vacuum, and found, as might be expected, that the light produced by the electricity passing through the vapour of the chloride was much more brilliant than that produced by it in passing through the vapour of the oil; and in the last it was more brilliant than in the vapour of mercury at common temperatures: the lights were of different colours, being of a pure white in the vapour of the chloride,

and of a red, inclined to purple, in that of the oil; and in both cases permanent elastic fluid was produced by its transmission.

The law of the diminution of the density of vapours by diminution of temperature, has not been accurately ascertained; but I have no doubt, from the experiments of Mr. DALTON, and some I have made myself, that it is represented by a geometrical progression; the decrements of temperature being in arithmetical progression; and in three pure fluids that I operated upon,* the ratio seemed nearly uniform for the same number of degrees below the boiling point; and (taking intervals of 20 degrees of temperature) .869416. Upon this datum, and considering the boiling points of mercury to be 600°, that of oil 540°, that of the chloride of antimony 340°, and that of tin 5000° all above 52°, and the elastic force of vapour of water at this temperature to be equal to raise by its pressure about .45 parts of an inch of mercury; the relative strengths of vapour will be, for mercury 000015615, for oil 0016819, for chloride of antimony 01692, and for tin 37015, preceded by 48 zeros.†

It is not known whether the vapour from solids follows a similar law of progression as that from fluids, and these numbers are only given to show how minute the quantity of matter must be in vapours where its effects are distinct upon electrical phenomena; and how much more minute it must be in the case of mercury artificially cooled; and almost beyond imagination so in vapours from substances requiring very elevated temperatures for their ebullition.

* Water, chloride of phosphorus, and alcohol or carburet of sulphur.

† I am obliged to CHARLES BABBAGE, Esq. F. R. S. for these calculations.

I made some comparative experiments to ascertain whether below the freezing point of water, the diminution of the temperature of the torricellian vacuum diminished its power of transmitting electricity, or of being rendered luminous by it. To about 20° this appeared to be the case; but between 20° above and 20° degrees below zero, the lowest temperature I could produce by pounded ice and muriate of lime, it seemed stationary; and as well as I could determine, the electrical phenomena were nearly of the same intensity as those produced in the vacuum above tin.

Unless the electrical machine was very active, no light was visible during the transmission of the electricity; but that this transmission took place, was evident from the luminous appearance of the rarefied air in the other parts of the syphon, and from the diminution of the repulsion of the ball of the quadrant electrometer attached to the prime conductor. When the machine was in great activity, there was a pale phosphorescent light above, and a spark on the mercury below, and brilliant light in the common vacuum. A Leyden jar *weakly* charged could not be made to transmit its electricity by explosion through the cooled torricellian vacuum, but this electricity was slowly dissipated through it; and when *strongly* charged, the spark passed through nearly as much space as in common air, and with a light visible in the shade. At all temperatures below 200°, the mercurial vacuum was a much worse conductor than highly rarefied air: and when the tube containing it was included in the exhausted receiver, its temperature being about 50°, the spark passed through a distance six times greater in the Boylean than in the mercurial vacuum.

It is evident from these general results that the light (and

probably the heat) generated in electrical discharges depends *principally* on some properties or substances belonging to the ponderable matter through which it passes; but they prove likewise that space, where there is no appreciable quantity of this matter, is capable of exhibiting electrical phenomena: and, under this point of view, they are favourable to the idea of the phænomena of electricity being produced by a highly subtile fluid or fluids, of which the particles are repulsive, with respect to each other, and attractive of the particles of other matter. On such an abstruse question, however, there can be no demonstrative evidence. It may be assumed, as in the hypothesis of Hooke, Huygens, and Euler, that an ethereal matter, susceptible of electrical affections, fills all space; or that the positive and negative electrical states, may increase the force of vapour from the substances in which they exist; and there is a fact in favour of this last idea which I have often witnessed—when the voltaic discharge is made in the Boylean vacuum, either from platinum or charcoal, in contact with mercury, the discharging surfaces require to be brought very near in the first instance; but the electricity may be afterwards made to pass to considerable distances through the vapour generated from the mercury or charcoal by its agency;—and when two surfaces of highly fixed metal, such as platinum or iron are used, the discharge will pass only through a very small distance, and cannot be permanently kept up.

The circumstance, that the intensity of the electrical light in the mercurial vacuum diminishes as it is cooled to a certain point, when the vapour must be of almost infinitely small density, and is then stationary, seems strongly opposed to the idea, that it is owing to any *permanent* vapour emitted

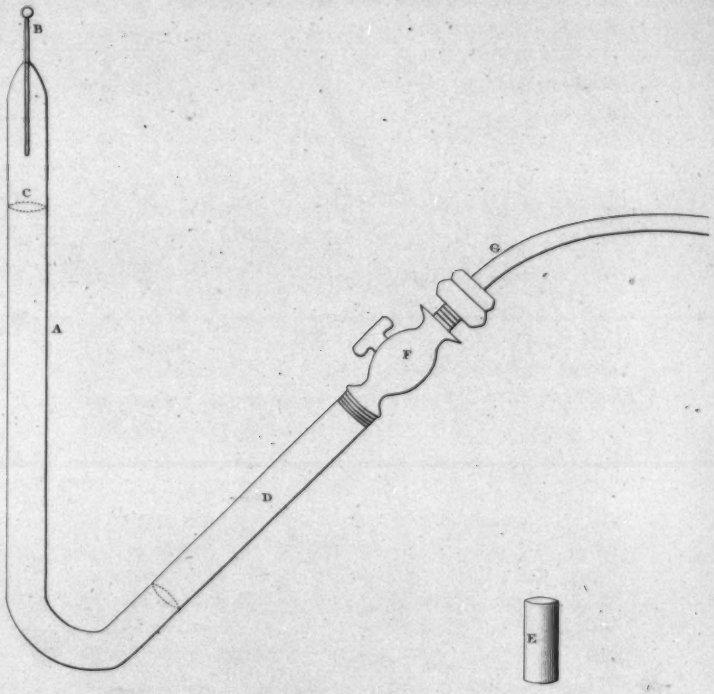
constantly by the mercury. The results with tin must be regarded as more equivocal; because as this substance cannot be boiled in vacuo, it may be always suspected to have emitted a small quantity of the rare air or gas to which it has been exposed; yet, supposing this circumstance, such gas must be at least as highly expanded as the vapour from cooled mercury, and can hardly be supposed capable of affording the dense light, which the passage of the electricity of the charged Leyden phial through the vacuum produces.

When the intense heat produced by electricity is considered, and the strong attractive powers of differently electrified surfaces, and the rapidity of the changes of state, it does not seem at all improbable, that the superficial particles of bodies, which, when detached by the repulsive power of heat, form vapour, may be likewise detached by electrical powers, and that they may produce luminous appearances in a vacuum, free from all other matter by the annihilation of their opposite electrical states.

In common cases of electrical action, the quantity of the heat generated by the annihilation of the different electrical states depends, as I stated in my last communication to the Society, upon the nature of the matter on which it acts; and in cases when electrical sparks are taken in fluids, vapour or gas is always generated; and in elastic fluids, the intensity of the light is always greater, the denser the medium. The luminous appearances therefore, it is evident from all the statements, must be considered as secondary; whilst the uniform exertions of electrical attractions and repulsions, under all circumstances, in rare and dense media and in vacuo, and with respect to solids, fluids, and gases, point them out (whe-

ther they be specific affections of a subtile imponderable fluid, or peculiar properties of matter) as primary and invariable electrical phenomena.

I have mentioned in the last page the suspicion, that melted tin may contain air. I shall conclude this paper by stating the grounds of this suspicion, and noticing a circumstance which appears to be of considerable importance, both in relation to the construction of barometers and thermometers, and to the analysis of gaseous bodies. Recently distilled mercury that has been afterwards boiled and cooled in the atmosphere, and which presents a perfectly smooth surface in a barometer tube, emits air when strongly heated in vacuo, and that in quantities sufficient to cover the whole interior of the tube with globules; and on keeping the stop-cock of one of the tubes used in the experiments on the mercurial vacuum open for some hours, it was found that the lower stratum of mercury had imbibed air, for when heated in vacuo, it emitted it distinctly from a space of a quarter of an inch of the column; smaller quantities were disengaged from the next part of the column; and its production ceased at about an inch high in the tube. There is great reason to believe, that this air exists in mercury in the same invisible state as in water, that is distributed through its pores; and the fact shows the necessity of long boiling the mercury in barometer and thermometer tubes, and the propriety of exposing as small a surface of the mercury as possible to the air. It may explain, likewise, the difference of the heights of the mercury in different barometers; and seems to indicate the propriety of reboiling the mercury in these instruments after a certain lapse of time.


B
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## EXPLANATION OF THE PLATE.

### Plate V.

A. The tube, of the usual diameter.

B. The wire for communicating electricity.

E. A small cylinder of metallic foil, to place as a cap on tubes not having the wire B, to make a coated surface.

C. The surface of the quicksilver, or fused tin.

D. The part of the tube to be exhausted by the stop-cock F, after being filled by means of the same stop-cock, when necessary, with hydrogene.

G. The moveable tube connected with the air-pump.

It is evident, that by introducing more mercury, the leg D may be filled with mercury, and the stop-cock closed upon it, so as to leave only a torricellian vacuum in the tube, in which the mercury may be boiled. I have found that the experiment tried in this way, offers no difference of result.

IX. *Croonian Lecture. On the anatomical structure of the Eye; illustrated by microscopical drawings, executed by F.* BAUER, *Esq. By Sir* EVERARD HOME, *Bart. V. P. R. S.*

Read November 15, 1821.

HAVING found an extraordinary advantage from Mr. BAUER's microscopical observations, when applied to anatomical investigations of other organs of animals, I requested him to give me his assistance in the examination of the different parts of the eye in the human species, quadrupeds, and birds.

In the first place, I wished him to ascertain whether the marsupium in the bird's eye is muscular; as I had advanced such an opinion in the Lecture for 1795. After the most careful examination, he has decided that it is not; but is a fine vascular membrane, as represented in the annexed drawing, which Dr. YOUNG had long considered it The real structure of the marsupium being thus completely established, I was led to inquire what parts, contained within the globe of the eye, are possessed of muscular fibres. Mr. BAUER, on examining the ciliary processes, found that the anterior layer is made up of about 80 processes, lying directly behind the iris, and with it firmly attached at the base to the choroid and sclerotic coat: these are membranous, very vascular, and the surface next the lens concave; that next the iris, convex. They are distinctly shown in the annexed drawings.

Between these membranous processes there are bundles of muscular fibres of $\frac{1}{100}$ of an inch in length, which I believe have not before been described: they originate all round from the capsule of the vitreous humor, pass forward over the edge of the lens, are attached firmly to its capsule and there terminate, as is seen in the drawings. They are unconnected with the ciliary processes, or iris. In the human eye, and that of the quadruped, they form bundles with intermediate spaces. In the bird, they are nearly one continued layer of muscular fibres. The choroid coat, which may be said to terminate anteriorly at the ciliary processes, is membranous in its structure; so far similar to the marsupium of the bird when unfolded; but in the choroid coat, Mr. BAUER has discovered lymphatic vessels, one on each side of every principal artery, not before ascertained, although there could be no doubt of their existence; and the arteries, as will be seen in the drawings, have not the usual direction, but run parallel to one another, totally unlike those in the marsupium.

In the quadrupeds with the tapetum lucidum, the nigrum pigmentum is principally deposited between the sclerotic and choroid coat. In the human eye and that of the bird, between the choroid coat and retina, a thin pellucid covering being interposed between it and the expansion of the optic nerve; the marsupium has a similar covering between the nigrum pigmentum and the vitreous humor. The colour of the nigrum pigmentum differs in intensity according to the colour of the hair; and when the animal is quite white, appears to be altogether wanting. That the marsupial membrane secretes the nigrum pigmentum, there can be no doubt; and for that purpose it is very abundantly supplied with large

arteries. That the choroid in the human eye, as well as that of the bird does the same, is in some measure proved by the fine injection thrown into the arteries of that membrane escaping from their termination, so as to form a layer of injection behind the retina without the smallest appearance of extravasation.

The membrane between the nigrum pigmentum and retina, has been described by Dr. Jacob, of Dublin, and his account of it published in the Philosophical Transactions. The nigrum pigmentum appears to be nothing more than the colouring matter of the red globules, rendered black in the act of separation from the arteries; it is also deposited upon the surface of the ciliary processes and iris, by the arteries with which they are loaded, and covered by a pellucid membrane.

In the horse, the arteries of the ciliary processes are very large; and I am led to believe that the extraordinary disease that animal is liable to in India, of having two species of worms (the strongylus armatus and filiaris papillosa) found alive in the aqueous humor, is produced by the ova or young worms escaping from the terminations of those arteries; more especially as Mr. Hodgson, in his engravings of diseased arteries, has figured the strongylus armatus adhering to the inner membrane of the superior mesenteric artery of the horse, showing that in that animal it gets into the circulation.

The iris is fixed at its origin to the annular ligament; is divisible into two layers; the posterior, muscular; the fibres radiating towards the pupil, at which part there is a regular sphincter muscle; the anterior, membranous.

My friend Mr. Maunoir, of Geneva, is, I believe, the first person who made out this structure, and gave an engraving of

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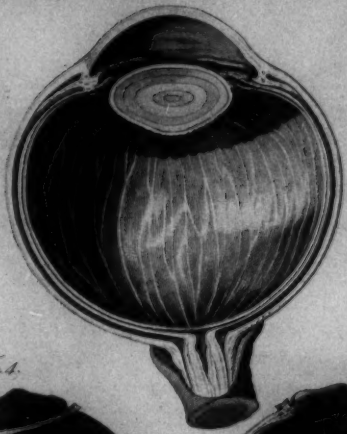
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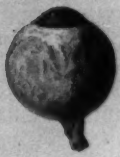
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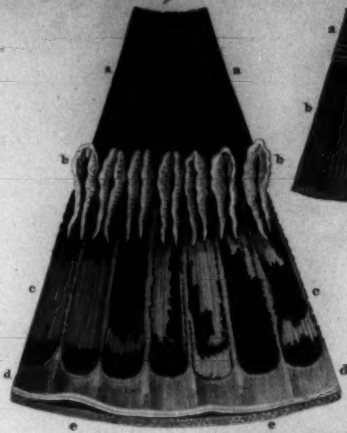


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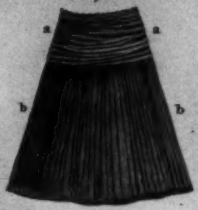


Fig. 3.

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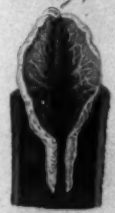

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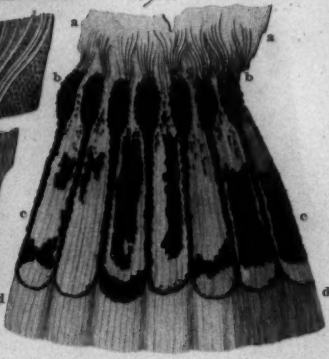


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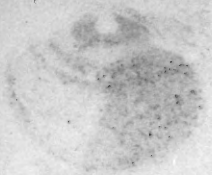

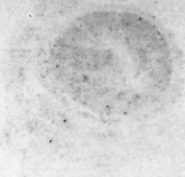

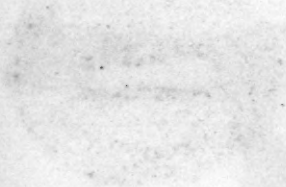

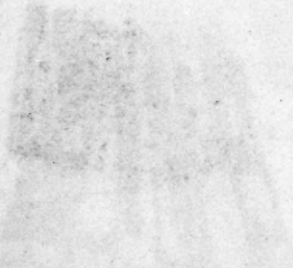

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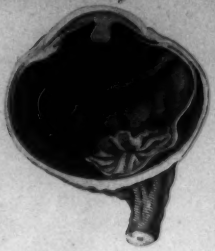

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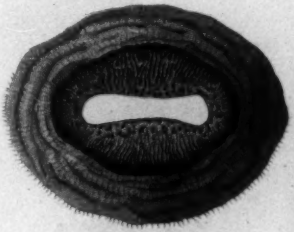

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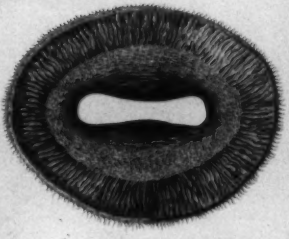

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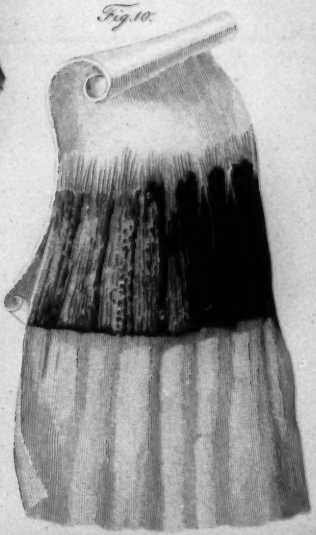

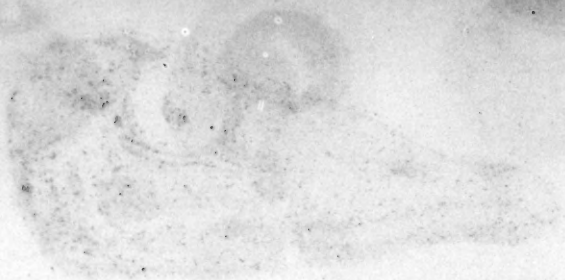

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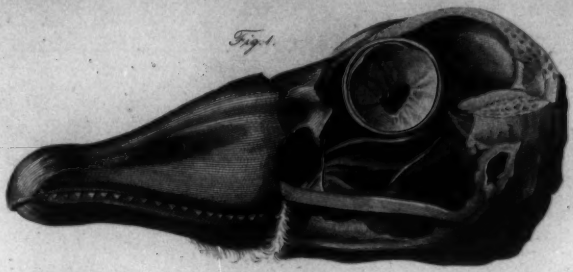

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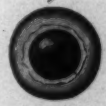

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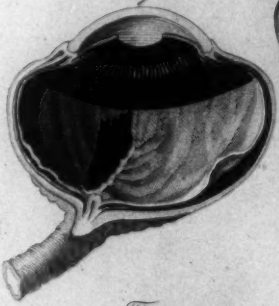

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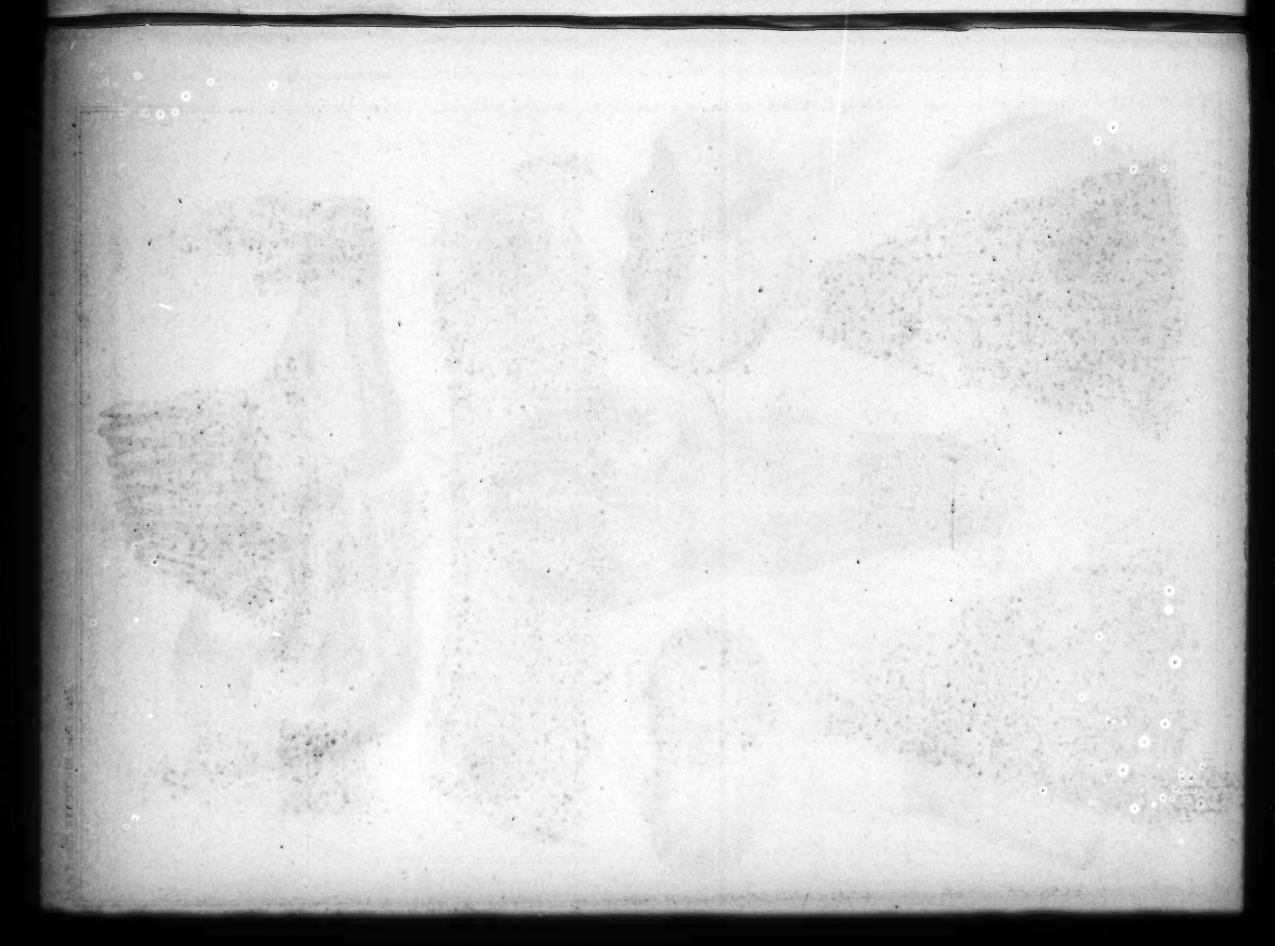

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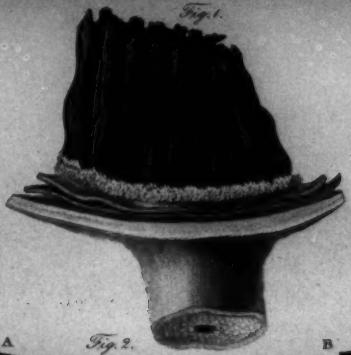

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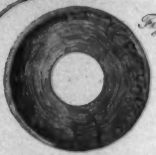

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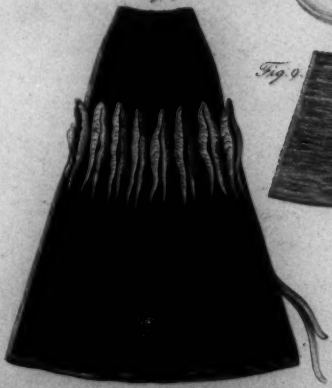

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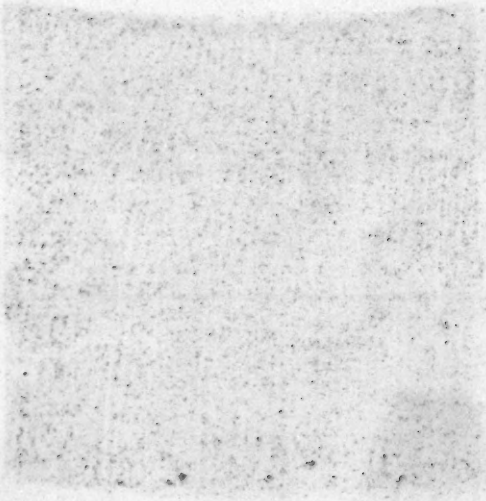

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Fig. 2.

Fig. 3

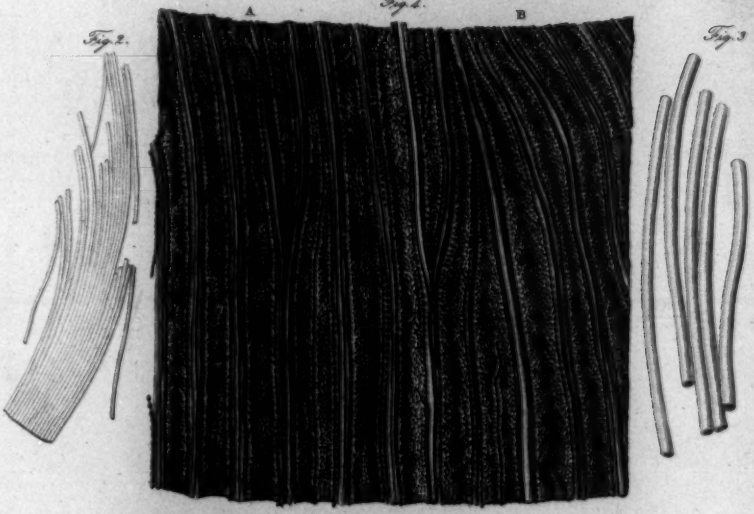
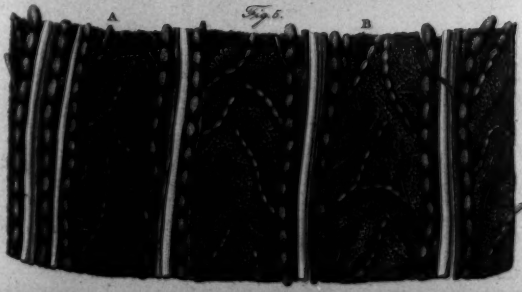



Fig. 5.



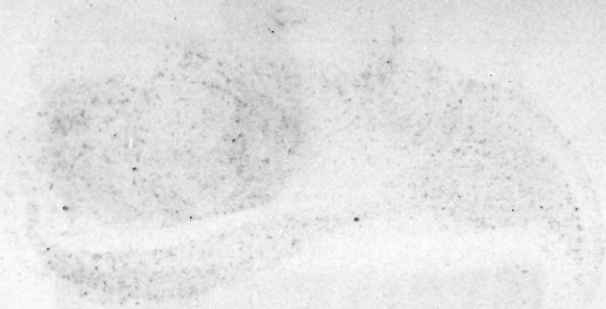


Fig. 1.

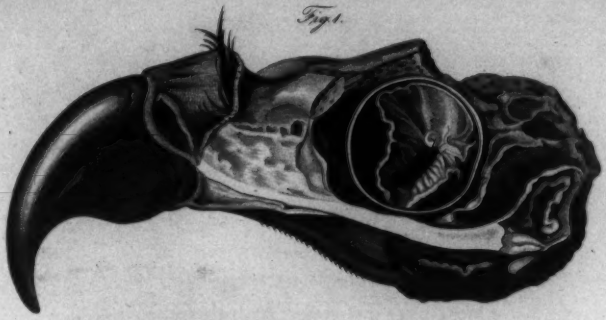


Fig. 2.

Franz. Bauer del.t

F. Bauer sc.

it. I have much pleasure in stating, that what he represented in the quadruped, corresponds with Mr. BAUER's drawings from the human eye, made before Mr. MAUNOIR's Treatise on the artificial pupil was shown to him. The capsule of the crystalline lens is made up of two hemispheres of different texture, in which the lens is completely enclosed; the anterior portion is more dense than the other. The posterior is so thin, as to appear a continuation of the capsule of the vitreous humor, but from its curling up when cut, it must partake of the same nature as the anterior portion. The vitreous humor consists of a very delicate gelatinous substance, exceedingly elastic, abundantly supplied with branches of vessels. Arteries are sometimes met with carrying red blood, and in a degree capable of being injected.

The fibres of the lens have the appearance of hairs like those formed in spun glass.

The situation of the marsupium is shown both in the eagle and goose, and the difference of its radius of curvature at the bottom of the eye on its two sides, is as $\frac{1}{10}$ to $\frac{1}{40}$th of an inch.

## EXPLANATION OF THE PLATES.

### PLATE VI.

Fig. 1. Front view of the human eye, extracted from its orbit; natural size.

Fig. 2. Side view of the same; natural size.

Fig. 3. Vertical section of the same; magnified three diameters.

Fig. 4. External side view of the human eye, the sclerotic coat and cornea being removed, showing the bundles of vessels which arise from the sclerotic coat, and go towards the ciliary ligament; magnified three diameters

Fig. 5. Internal view of a vertical section of the preceding figure, bringing to view the inside of the iris with the nigrum pigmentum, the ciliary processes, the radiated and pigmented circle in the anterior arch of the eye, the retina, and a portion of the medullary substance of the optic nerve and the choroid membrane; magnified three diameters.

Fig. 6. Side view of the vitreous humor and crystalline lens, taken out of the eye, to show the impression left on it by the pigment of the radiated circle, and ciliary processes; magnified three diameters.

Fig. 7. External view of the iris, consisting entirely of a plexus of vessels; magnified three diameters.

Fig. 8. Internal view of the iris, consisting of bundles of muscular fibres; those next to the pupil being orbicular, and the exterior radiated; magnified three diameters.

## PLATE VII.

Fig. 1. Internal view of a small portion of the iris of the human eye, the pigmentum nigrum being removed to show, *a*, *a*, the orbicular, and *b*, *b*, the radiated muscle; magnified ten diameters.

Fig. 2. Internal view of a portion of the membranous part of the human eye, consisting of *a*, *a*, a small portion of the iris with the pigment; *b*, *b*, the ciliary processes in their natural state; *c*, *c*, a portion of the radiated circle in the anterior arch of the eye, its pigment appears to have been disturbed by the vitreous humor being forcibly removed; *d*, *d*, the commencement of the retina, and *e*, *e*, the edge of the choroid membrane; magnified ten diameters.

Fig. 3. External view of the same; *a*, *a*, the iris, *b*, *b*, two of the ciliary processes, *c*, *c*, the seam or ligament by which all

these parts are joined to the sclerotic coat; *d*, *d*, the ciliary ligament, and *e*, *e*, the choroid membrane; magnified ten diameters.

Fig. 4. The same as the preceding figure, with the iris removed, to give a back view of the ciliary processes at *a*, *a*; *b*, *b*, shows the seam or ligament by which these parts are joined to the sclerotic coat; *c*, *c*, the ciliary ligament, and *d*, *d*, the choroid membrane; magnified ten diameters.

Fig. 5. An equally sized portion of the anterior part of the capsule of the crystalline lens, *a*, *a*, and of the capsule of the vitreous humor, *b*, *c*, *d*, exactly lying under, and corresponding with the preceding figures 2, 3, and 4, and showing the bundles of fibres, *b*, *b*, by which the capsule of the crystalline lens is connected with the capsule of the vitreous humor; and how the pigment from the ciliary processes, *b*, *b*, and from the radiated circle, *c*, *c*, is impressed on it; magnified ten diameters.

Fig. 6. A couple of the fibrous bundles, with the nigrum pigmentum nearly removed; magnified twenty diameters.

Fig. 7. Front view of one of the ciliary processes laid open, and the pigmentum removed, to show the plexus of vessels in its membranous wings, from which the nigrum pigmentum seems to be secreted; magnified twenty diameters.

Fig. 8. A back view of the same; magnified twenty diameters.

Fig. 9. An external view of a small portion of the choroid membrane; magnified ten diameters.

PLATE VIII.

Fig. 1. A front view of an injected bullock's eye; natural size.

Fig. 2. Side view of the same; natural size.

Fig. 3. Vertical section of the same; natural size.

Fig. 4. Side view of the vitreous humor and the crystalline lens; natural size.

Fig. 5. Outside view of the iris; magnified two diameters.

Fig. 6. Inside view of the same, the nigrum pigmentum being entirely removed; magnified two diameters.

Fig. 7. Inside view of a small portion of the iris, the nigrum pigmentum entirely removed; magnified eight diameters.

Fig. 8. A portion of the membranous coat of the eye, consisting of a small portion of the iris, the nigrum pigmentum partially removed, the injected ciliary processes, a portion of the choroid membrane slightly injected, and a very small portion of the retina adhering to it; magnified six diameters.

Fig. 9. One of the ciliary processes, finely injected; magnified ten diameters.

Fig. 10. A portion of the capsule of the vitreous humor, with its muscular fibres connecting it with the anterior part of the capsule of the crystalline lens; magnified six diameters.

PLATE IX.

Fig. 1. Side view of a dissected goose's head; natural size.

Fig. 2. Front view of the same; natural size.

Fig. 3. Front view of the left eye of the goose; natural size.

Fig. 4. Side view of the same; natural size.

Fig. 5. Vertical section of the left eye of the goose; magnified three diameters.

Fig. 6. The vitreous humor and crystalline lens of the same eye; magnified three diameters.

Fig. 7. Transverse section, or the posterior hemisphere of the same left eye; magnified three diameters.

Fig. 8. Represents at A, a portion of the anterior part of the capsule of the crystalline lens; at B, a very small portion of the posterior part of the capsule of the crystalline lens; and at C, a portion of the capsule or membrane of the vitreous humor, with the muscular fibres which connect it with the capsule of the lens; magnified ten diameters.

PLATE X.

Fig. 1. The marsupium of an injected goose's eye, in its natural state; magnified eight diameters.

Fig. 2. The same marsupium unravelled; at A, in the natural state, and at B, injected; magnified eight diameters.

Fig. 3. Front view of one of the ciliary processes, injected and expanded; magnified twenty diameters.

Fig. 4. Back view of the same; magnified twenty diameters.

Fig. 5. External view of the injected iris; magnified three diameters.

Fig. 6. Internal view of the same, the nigrum pigmentum removed; magnified three diameters.

Fig. 7. Internal view of a portion of the anterior hemisphere of the injected goose's eye, consisting of a portion of the iris, with the nigrum pigmentum, the ciliary processes in their natural position; the radiated circle, and a very small

portion of the injected choroid membrane; magnified ten diameters.

Fig. 8. External view of the same, showing the injected iris, the seam by which these parts are connected with the sclerotic coat, some of the bundles of vessels which arise from the sclerotic coat and enter under or about the connecting seam, part of the injected radiated circle, and a very small portion of the injected choroid membrane; magnified ten diameters.

Fig. 9. Internal view of a portion of the iris, the nigrum pigmentum being entirely removed; magnified ten diameters.

Fig. 10. Horizontal section of the crystalline lens of the goose's eye; magnified three diameters.

Fig. 11. Vertical section of the same; magnified three diameters.

PLATE XI.

Fig. 1. Represents, at A, a small portion of the retina, and, at B, a very small portion of that delicate membrane which lies between the retina and the nigrum pigmentum, and which is described by Dr. JACOB, in the Philosophical Transactions of 1819; magnified fifty diameters.

Fig. 2. A very small portion of a single lamella of the crystalline lens of the goose's eye, partly unravelled; magnified one hundred diameters.

Fig. 3. Some separated fibres of the same; magnified four hundred diameters.

Fig. 4. A $\frac{1}{100}$th part of a square inch of the choroid membrane of the injected goose's eye; the portion at A, is in the

natural state, and that at B, is injected; magnified forty diameters.

Fig. 5. A very small portion of the same; at A, in the natural state, and at B, injected; magnified two hundred diameters.

## Plate XII.

Fig. 1. Side view of a dissected eagle's head; natural size.

Fig. 2. Front view of the same; natural size.

X. *A Letter from* JOHN POND, *Esq. Astronomer Royal, to Sir* HUMPHRY DAVY, *Bart. President of the Royal Society, relative to a derangement in the Mural Circle at the Royal Observatory.*

Read November 22, 1821.

MY DEAR SIR,

THE interest which the Royal Society has always taken in every thing relating to this Observatory, and to which may be attributed its present prosperous condition, will, I trust, render unnecessary any apology for this communication.

I wish to make known to astronomers, as soon as possible, a derangement that has for some time past existed in the mural circle, and of which I have not, till lately, been able to ascertain the cause with certainty.

This derangement began, I believe, about the autumn of the year 1819; the position of the telescope was then changed; and from that time the error has been gradually increasing till last summer, when the cause was distinctly ascertained, and the proper remedy applied.

In the Preface to the Greenwich Observations for the year 1820, now printing, I shall have an opportunity of stating the amount of this error, and the correction which should be applied to the observations made within the two last years. At present it will be sufficient to mention, in as few words as possible, the cause of this error.

Those who are acquainted with the construction of the

Greenwich Mural Circle, are aware, that though the telescope may be applied to every part of the circle, yet, when fixed for observation, the principle of the instrument requires that the tube, especially at its extremities, should be so firmly fixed to the circle as to form one piece with it: to accomplish this, connecting braces are attached at each end of the telescope.—It now appears that these braces have, in progress of time, become insecure, owing to the screws which fastened them having given way. The effect of this will be, to permit the ends to bend from the centre instead of retaining, as they ought to do, an invariable position with respect to the circle. Under these circumstances, when the telescope is directed to the zenith, the position may be considered as free from error; but when the instrument is moved either towards the north or south horizon, should either extremity bend more than the other, an error will take place, and will increase from the zenith towards the horizon, but in what exact proportion, remains to be determined by future observations.

The cause of this error being thus ascertained, Mr. TROUGHTON has applied additional braces to connect the telescope with the circle, sufficiently strong, I should conceive, to prevent the possibility of such an accident for the future.

This alteration has already produced such an improvement in the observations, as prove sufficiently that the source of error has not been mistaken. Of the published observations, only those made in the three last months of the year 1819 are affected by this error, and that in so very small a degree, as must have entirely escaped notice, had it not afterwards increased.

During the year 1820 the error increased; but did not, I believe, in the distance from the pole to the equator amount to two seconds; at altitudes lower than Sirius, and at the altitude of the sun at the winter solstice, the error may have been greater than two seconds, but did not exceed four.

But after the month of February 1821, the error rapidly increased; and this ultimately led to a discovery of the cause.

My present object in this letter, is simply to state these circumstances to the Society. I shall defer a more detailed account of the nature of this derangement, and of its effects, till I shall be enabled, by a sufficient number of observations made with the instrument in its improved state, to ascertain, with some degree of certainty, at what period the derangement took place, and what corrections are required to be applied, till the instrument was restored to its perfect state.

I have the honor to be,

My DEAR SIR,

with the highest regard,

your most obedient humble Servant,

JOHN POND.

Royal Observatory,
Nov. 21, 1821.

## XI. *On the finite extent of the Atmosphere.* By William Hyde Wollaston, *M. D. V. P. R. S.*

Read January 17, 1822.

The passage of Venus very near the sun in superior conjunction in the month of May last, having presented an opportunity of examining whether any appearance of a solar atmosphere could be discerned, I am in hopes that the result of my endeavours, together with the views which induced me to undertake the inquiry, may be found deserving of a place in the Philosophical Transactions.

If we attempt to estimate the probable height to which the earth's atmosphere extends, no phenomenon caused by its refractive power in directions at which we can view it, or by reflection from vapours that are suspended in it, will enable us to decide this question.

From the law of its elasticity, which prevails within certain limits, we know the degrees of rarity corresponding to different elevations from the earth's surface; and if we admit that air has been rarefied so as to sustain only $\frac{1}{100}$ of an inch barometrical pressure, and that this measure has afforded a true estimate of its rarity, we should infer from the law, that it extends to the height of forty miles, with properties yet unimpaired by extreme rarefaction. Beyond this limit we are left to conjectures founded on the supposed divisibility of matter: and if this be infinite, so also must be the extent of

our atmosphere. For, if the density be throughout as the compressing force, then must a stratum of given thickness at every height be compressed by a superincumbent atmosphere, bearing a constant ratio to its own weight, whatever be its distance from the earth. But if air consist of any ultimate particles no longer divisible, then must expansion of the medium composed of them cease at that distance, where the force of gravity downwards upon a single particle is equal to the resistance arising from the repulsive force of the medium.

On the latter supposition of limited divisibility, the atmosphere which surrounds us will be conceived to be a medium of finite extent, and may be peculiar to our planet, since its properties would afford no ground to presume that similar matter exists in any other planet. But if we adopt the hypothesis of unlimited expansion, we must conceive the same kind of matter to pervade all space, where it would not be in equilibrio, unless the sun, the moon, and all the planets possess their respective shares of it condensed around them, in degrees dependent on the force of their respective attractions, excepting in those instances where the tendency to accumulate may be counteracted by the interference of other kinds of matter, or of other powers of which we have no experience, and concerning which we cannot expect to reason correctly.

Now, though we have not the means of ascertaining the extent of our own atmosphere, those of other planetary bodies are nevertheless objects for astronomical investigation; and it may be deserving of consideration, whether, in any instance, a deficiency of such matter can be proved, and whe-

ther, from this source, any conclusive argument can be drawn in favour of ultimate atoms of matter in general. For, since the law of definite proportions discovered by chemists is the same for all kinds of matter, whether solid, or fluid, or elastic, if it can be ascertained that any one body consists of particles no longer divisible, we then can scarcely doubt that all other bodies are similarly constituted; and we may without hesitation conclude that those equivalent quantities, which we have learned to appreciate by proportionate numbers, do really express the relative weights of elementary atoms, the ultimate objects of chemical research.

These reflections were originally suggested by hearing an opinion hazarded without due consideration, that the non-existence of perceptible atmosphere around the moon, might be regarded as conclusive against the indefinite divisibility of matter. There was, however, an oversight in this inference, as the quantity of such matter, which the moon would retain around her, could not possibly be perceived by the utmost power of any instruments hitherto invented for astronomical purposes. For, since the density of an atmosphere of infinite divisibility at her surface would depend on the force of her gravitation at that point, it would not be greater than that of our atmosphere is where the earth's attraction is equal to that of the moon at her surface. At this height, which by a simple computation is about 5000 miles from the earth's surface, we obviously can have no perceptible atmosphere, and consequently, should not expect to discern an atmosphere of similar rarity around the moon.

It is manifestly in the opposite direction that we are to look for information. We should examine first that body

which has the greatest power, and see whether even there the non-appearance of those phenomena which might be expected from such an atmosphere, will warrant the inference that our own is confined to this one planet by the limit set to its divisibility.

By converse of the same rule which gives an estimate of extreme rarity at the moon's surface, we may form a conception at what distance round the sun refraction from such a cause should be perceived. If we calculate at what apparent distance from the body of the sun his force is equal to that of gravity at the surface of the earth, it is there that his power would be sufficient to accumulate (from an infinitely divisible medium filling all space) an atmosphere* fully equal in density to our own, and consequently producing a refraction of more than one degree, in the passage of rays obliquely through it.

If the mass of the sun be considered as 330.000 times that of the earth, the distance at which his force is equal to gravity will be $\sqrt{330.000}$, or about 575 times the earth's radius; and if his radius be 111,5 times that of the earth, then this distance will be $\frac{575}{111.5}$ or 5.15 times the sun's radius; and $15' 49'' \times 5{,}15 = 1^{\circ}\,21'\,29''$, will be the apparent distance from the sun's centre on the 23d of May, when the following observations were made.

What deduction should be allowed for the effect of heat,

* Such an atmosphere would, in fact, be of greater density on account of the far greater extent of the medium affected by the solar attraction, although of extreme rarity; but the addition derived from this source, may be disregarded in the present estimate, without prejudice to the argument, which will not be found to turn upon any minute difference.

it may be time to consider when we have learned the amount of apparent refraction at some given distance; and we may then begin to conjecture, whether heat can counteract the increase of density that would occur in the approach of only $\frac{1}{10}$ of a second towards his centre.*

As I had not any instrument in my possession that I considered properly adapted for the purpose, I requested the assistance of several astronomical friends in watching the progress of Venus to the sun for some days preceding superior conjunction, and in recovering sight of her afterwards. But neither the Astronomer Royal at Greenwich, nor Professor BRINKLEY of Dublin, nor Mr. SOUTH, with the admirable instruments they possess, were able to make any observation within the time required, not being furnished with the peculiar means adapted to this inquiry.

Captain KATER, however, who entered fully into my views, and engaged in the prosecution of them with all the ardour necessary for success, by using a reflecting telescope, was able to furnish me with a valuable set of observations, $3\frac{1}{2}$ days preceding conjunction, which, together with those in which I had the good fortune to succeed at nearly an equal interval subsequent to the passage, afford data quite sufficient to show, that no refraction is perceptible at the period

* If we attempt to reason upon what would be the progressive condensation of such an atmosphere downwards towards the surface of the sun, we are soon stopped by the limit of our experience as to the degree of condensation of which the atmosphere is susceptible. If we could suppose the common law of condensation to extend as far as forty-six miles in depth, the density corresponding to it, would be about equal to that of quicksilver, from whence a refraction would occur exceeding all bounds of reasonable calculation. A space of forty-six miles at the distance of the sun from us, would subtend about $\frac{1}{10}$ of a second.

of our observations; and these come far within the specific distance above estimated.

A selection from the series given to me by Captain KATER is contained in the following table:

| | | Diff. R. A. | Diff. calc. from N. Alm. |
|---|---|---|---|
| | h. m. s. | m. s. | m. s. |
| May 18 | 2 40 25 | 4 25.6 | . . . |
| | 21 30 50 | 3 48.1 | . . . |
| | 23 27 58 | 3 38.8 | . . . |
| 19 | 0 0 0 | . . . | 3 37 |
| | | Diff. Decl. | |
| May 18 | 2 44 33 | 45 56 | |
| | 23 19 40 | 40 57 | |
| 19 | . . . | . . . | 40 36 |

It is evident, that in these observations the differences between the observed and calculated places of the planet, are not such as to indicate a refraction that can be relied on.

My own observations were very few in number, and not to be compared to the former in precision; but they are necessary to supply a deficiency when Captain KATER was at a distance from his instruments, and could make no observation.

On the 26th, between XI. 20 and XI. 30 I had three comparative observations, the best of which gave me the passage of Venus $3^m$ $55^s$ after the sun. The mean of two others being $3^m$ $49^s$. I consider the result as on the 25th, $23^h$ $24^m$. Diff. R. A. $5^m$ $52^s$.

The nearest second to be inferred from the Nautical Almanac for this time being $3^m$ $53^s$ after the sun, it is evident that no perceptible refraction occurred at this time.

From the observations of Captain KATER, no retardation of

the motion of Venus can be perceived in her progress toward the sun, as would occur from increasing refraction; and by comparison of her motion in the interval between his last observation and my own, with her change of place for the same interval given in the Nautical Almanac, there seems no ground whatever to suppose that her apparent position has been in the least affected by refraction through a solar atmosphere, although the distance at the time of Captain KATER's last observation was but 65′ 50″ from the sun's centre, and at the time of my own only 53′ 15″.

Although these distances appear small, I find that Venus has been seen at a still less distance by Mons. VIDAL of Montpellier in 1805.* On the 30th of May, he observed Venus 3$^m$ 16′ after the sun, when their difference of declination was not more than 1′, so that her distance from the centre was about 46 minutes of space. Since his observations also accord with the calculated places of Venus, they might have superseded the necessity of fresh observations, if I had been duly aware of the inference to be drawn from them.

The same skilful observer has also recorded an observation of Mercury on the 31st of March of the same year, when he was seen at about 65′ from the sun's centre.

If I were to describe the little telescope with which my observations were made, without taking due care to explain the precautions adopted, and the grounds of their efficacy, it might perhaps be scarcely credible, that with an object glass less than one inch in aperture, having a focal length of only seven inches, I could discern an object not to be seen by telescopes of four and five inches aperture. We know, how-

* Conn. des Tems. 1808.

ever, that this small aperture is abundantly sufficient for viewing Venus at a distance from the sun; and, since the principal obstruction to seeing her nearer (when the atmosphere is clear), arises from the glare of false light upon the object-glass, the success of the observation depends entirely on having an effectual screen for the whole object-glass, which is obviously far more easy to accomplish in the smaller telescope.

Since the screen which I employed was about six feet distant from my object-glass, a similar protection for an aperture of five inches would have required to be at the distance of thirty feet, to obviate equally the interference of the sun's light at the same period; but this is a provision with which regular observatories are not furnished for the common purposes of astronomy.

As I hope at some future time to avail myself of a larger aperture for such observations, without the necessity of mounting a more distant screen, it may be desirable that I should suggest to others the means by which this may be effected, if they think the question of a solar atmosphere worthy of farther investigation.

If an object-glass of four inches aperture be covered, so as to expose only a vertical slit of its surface one inch in width, the surface of glass to be so used is about five times as large as the circular aperture one inch in diameter, and yet will be as completely shaded by a vertical screen at any given distance: and an interval of only five feet, might allow a star or planet to be seen within a degree of the sun's disc.

When the sun and planet have the same declination, the vertical position of the slit is manifestly the most advantage-

ous that could be chosen on the meridian; but, for the purpose of seeing to the greatest advantage when the line of the centres is inclined to the horizon, it would be requisite to have the power of turning the slit and screen together at right angles to any line of direction of the centres.

The only fixed star sufficiently near to the ecliptic, and bright enough to give any prospect of its being seen near the sun, is Regulus, which passes between the 20th and 21st of August; but I have not yet had an opportunity of ascertaining within what distance from the sun this star can be discerned.

In the foregoing remarks, I have perhaps dwelt more upon the consideration of the solar atmosphere, than may seem necessary to those who have considered the common phenomena observable in the occultations of Jupiter's satellites by the body of the planet. Their approach, instead of being retarded by refraction, is regular, till they appear in actual contact; showing that there is not that extent of atmosphere which Jupiter should attract to himself from an infinitely divisible medium filling space.

Since the mass of Jupiter is full 309 times that of the earth, the distance at which his attraction is equal to gravity must be as $\sqrt{309}$, or about 17.6 times the earth's radius. And since his diameter is nearly eleven times greater than that of the earth, $\frac{17.6}{11} = 1.6$ times his own radius will be the distance from his centre, at which an atmosphere equal to our own should occasion a refraction exceeding one degree. To the fourth satellite this distance would subtend an angle of about $3^{\circ}\,37'$, so that an increase of density to $3\frac{1}{2}$ times our common

atmosphere, would be more than sufficient to render the fourth satellite visible to us when behind the centre of the planet, and consequently to make it appear on both (or all) sides at the same time.

The space of about six miles in depth, within which this increase of density would take place, according to known laws of barometric pressure, would not subtend to our eye so much as $\frac{1}{300}$ of a second, a quantity not to be regarded in an estimate, where so much latitude has been allowed for all imaginable sources of error.

Now though, with reference to the solar atmosphere, some degree of doubt may be entertained in consequence of the possible effects of heat which cannot be appreciated, it is evident that no error from this source can be apprehended in regard to Jupiter; and as this planet certainly has not its due share of an infinitely divisible atmosphere, the universal prevalence of such a medium cannot be maintained; while, on the contrary, all the phenomena accord entirely with the supposition that the earth's atmosphere is of finite extent, limited by the weight of ultimate atoms of definite magnitude no longer divisible by repulsion of their parts.

## XII. *On the expansion in a series of the attraction of a Spheroid.*

*By* James Ivory, *M. A. F. R. S.*

Read January 17, 1829.

The purpose of this paper is to make some observations on the developement of the attractions of spheroids, and on the differential equation that takes place at their surface.

1. The whole of this doctrine depends on one fundamental proposition. Let $f(\theta, \varphi)$ denote any function of the sines and cosines of the variable arcs $\theta$ and $\varphi$; and put $\mu = \cos\theta$: then the given function may be developed in a series, viz.

$$f(\theta, \varphi) = Q^{(0)} + Q^{(1)} + Q^{(2)} \ldots + Q^{(i)} \ldots \text{ \&c.}$$

every term of which will separately satisfy this equation in partial fluxions, viz.

$$\frac{d \cdot \left\{(1-\mu^2)\frac{dQ^{(i)}}{d\mu}\right\}}{d\mu} + \frac{1}{1-\mu^2} \cdot \frac{d^2 Q^{(i)}}{d\varphi^2} + i(i+1)\,Q^{(i)} = 0.$$

Now in one case there is no difficulty. Whenever $f(\theta, \varphi)$ stands for a rational and integral function of $\mu$, $\sqrt{1-\mu^2} \cdot \sin\varphi$, $\sqrt{1-\mu^2} \cdot \cos\varphi$; or of three rectangular co-ordinates of a point in the surface of a sphere; the proposition is clear. In this case the same combinations of the variable quantities are found in the terms of the series and in the given function; and by employing the method of indeterminate coefficients, the two expressions may be made to coincide. The inquiry is therefore reduced to examine the nature of the developement when $f(\theta, \varphi)$ is not such a function as has been men-

tioned. One thing is indisputable. Since the terms of the developement contain no quantities, except such as arise from combining three rectangular co-ordinates, it follows, that when $f(\theta, \varphi)$ is not explicitly a function of $\mu$, $\sqrt{1-\mu^2} \cdot \sin \varphi$, $\sqrt{1-\mu^2} \cdot \cos \varphi$, it must be considered as transformed into such a function. Algebraically speaking, the transformation is no doubt always possible; but there may be danger that, by proceeding in this way, we fall upon expressions which are not proper representatives of the given function; which are symbolical merely, and which cannot be safely employed in the investigation of truth.

In order to fix the imagination, and to avoid every sort of uncertainty and obscurity, I shall take a particular, although a very extensive case of the general expression. I shall suppose that $f(\theta, \varphi)$, or more shortly $y$, denotes a rational and integral and finite function of the four quantities, $\sin \theta$, $\cos \theta$, $\sin \varphi$, $\cos \varphi$. We may then substitute for the powers and products of $\sin \varphi$ and $\cos \varphi$, their values in the sines and cosines of the multiples of the arc; by which means we shall obtain,

$$y = M^{(0)} + M^{(1)} \cos \varphi + M^{(2)} \cos 2\varphi + \&c.;$$
$$+ N^{(1)} \sin \varphi + N^{(2)} \sin 2\varphi$$

the symbols $M^{(0)}$, $M^{(1)}$, $N^{(1)}$ &c. standing for rational and integral functions of $\cos \theta$ and $\sin \theta$, or of $\mu$ and $\sqrt{1-\mu^2}$. Again, every even power of $\sqrt{1-\mu^2}$ is an integral function of $\mu$; and every odd power is equal to a similar function multiplied by $\sqrt{1-\mu^2}$: the value of $y$ will therefore be thus expressed;

$$y = \left(F(\mu) + \sqrt{1-\mu^2} \cdot f(\mu)\right) + \left(F^{(1)}(\mu) + \sqrt{1-\mu^2} \cdot f^{(1)}(\mu)\right) \cos \varphi + \&c.$$
$$+ \left(G^{(1)}(\mu) + \sqrt{1-\mu^2} \cdot g^{(1)}(\mu)\right) \sin \varphi$$

all the functional quantities being integral expressions of $\mu$. The general term of this expression is

$$\left\{ F^{(i)}(\mu) + \sqrt{1-\mu^2}.f^{(i)}(\mu) \right\} \cos i\varphi$$
$$+\left\{ G^{(i)}(\mu) + \sqrt{1-\mu^2}.g^{(i)}(\mu) \right\} \sin i\varphi;$$

and by multiplying by $\frac{(1-\mu^2)^{\frac{i}{2}}}{(1-\mu^2)^{\frac{i}{2}}}$, or $1$, it will become,

$$\left\{ \frac{F^{(i)}(\mu)}{(1-\mu^2)^{\frac{i}{2}}} + \frac{f^{(i)}(\mu)}{(1-\mu^2)^{\frac{i-1}{2}}} \right\} (1-\mu^2)^{\frac{i}{2}} \cos i\varphi$$
$$+\left\{ \frac{G^{(i)}(\mu)}{(1-\mu^2)^{\frac{i}{2}}} + \frac{g^{(i)}(\mu)}{(1-\mu^2)^{\frac{i-1}{2}}} \right\} (1-\mu^2)^{\frac{i}{2}} \sin i\varphi;$$

and finally, by expanding the denominators, we get,

$$M^{(i)}(1-\mu^2)^{\frac{(i)}{2}} \cos i\varphi + N^{(i)}(1-\mu^2)^{\frac{i}{2}} \sin i\varphi;$$

the symbols $M^{(i)}$ and $N^{(i)}$ denoting rational series of the powers of $\mu$. By performing these operations in all the terms containing $\varphi$, and likewise by expanding the radical $\sqrt{1-\mu^2}$ in the first term, the value of $y$ will be thus expressed;

$$y = M^{(0)} + M^{(1)}(1-\mu^2)^{\frac{1}{2}} \cos\varphi + M^{(2)}(1-\mu^2)^{\frac{2}{2}} \cos 2\varphi + \&c.$$
$$+ N^{(1)}(1-\mu^2)^{\frac{1}{2}} \sin\varphi + N^{(2)}(1-\mu^2)^{\frac{2}{2}} \sin 2\varphi$$

all the functional symbols standing for series of the powers of $\mu$. The given expression now consists entirely of combinations of the quantities $\mu$, $\sqrt{1-\mu^2}.\cos\varphi$, $\sqrt{1-\mu^2}.\sin\varphi$; that is, it is a function of three rectangular co-ordinates.

The same end might have been accomplished by a shorter and more simple process, which will apply to every function of two variable arcs.

Put $u = \sqrt{1-\mu^2} \cdot \sin \varphi$, $x = \sqrt{1-\mu^2} \cdot \cos \varphi$; then

$$\cos \theta = \mu$$

$$\sin \theta = \sqrt{1-\mu^2}$$

$$\sin \varphi = \frac{u}{\sqrt{1-\mu^2}}$$

$$\cos \varphi = \frac{x}{\sqrt{1-\mu^2}};$$

and by substituting these values and expanding the radical quantities wherever they occur, $y$ will be transformed into a function of $\mu$, $u$, $x$, or of three rectangular co-ordinates. The former process has been chosen under the idea, that it exhibits more clearly the quantities which are in a manner extraneous to the function, and are introduced merely for the purpose of making it put on a certain form.

Having now reduced $y$ to a function of three rectangular co-ordinates, the developement in question will be obtained by the method of indeterminate coefficients already mentioned. Nothing more is necessary than to form the quantities $Q^{(0)}$, $Q^{(1)}$, $Q^{(2)}$, &c., giving to each the most general expression, and leaving the coefficients indeterminate; then the sum of these terms will contain the same combinations of $\mu$, $\sqrt{1-\mu^2} \cdot \sin \varphi$, $\sqrt{1-\mu^2} \cdot \cos \varphi$, that $y$ does; and by making the two expressions coincide, we shall obtain,*

$$y = Q^{(0)} + Q^{(1)} + Q^{(2)} \ldots + Q^{(i)} \cdot \&c.$$

Now let us go back to the original expression of $y$. By following the process described in the second chapter of the third book of the *Mecanique Celeste*, a similar developement of that quantity will be obtained. But it is proved, in the same chapter, that a given function cannot be developed two diffe-

* Mecanique Celeste, Tom. ii. p. 42.

rent ways, in a series of terms that satisfy the general equation in partial fluxions:* and from this it appears, that the developement obtained by the algebraic operations described above, is identical with the developement found by LAPLACE's method.

There is another way of expressing the terms of the developement of $y$, namely, by definite integrals. But upon this head there is no difficulty, when the possibility of the developement is allowed. The question is not concerning the properties of a series of quantities that satisfy the general equation of partial fluxions; but whether the developement can be admitted in all cases as a fit instrument for the investigation of truth.

Since it has been shown that the developement of $y$, obtained by the procedure in the second chapter of the third book of the *Mecanique Celeste*, is the same with the like developement found by immediately transforming the given expression into a function of three rectangular co-ordinates; it is just to say of the former method, that in reality it is nothing more than a particular way of effecting such a transformation, while at the same time it gives to the transformed quantity a certain arrangement. In the process we have followed, there is no need to employ the differential equation that takes place at the surface of the spheroid; and by thus going more directly to the foundations of the method, we can discern more clearly what goes on under the cover of many complicated analytical operations. There is an essential distinction with regard to the developement to be observed between the two cases when the given expression $y$ is explicitly a function

* Mec. Cel. Tom. II. pp. 32, and 33.

of three rectangular co-ordinates, and when it must be made to assume the form of such a function by a transformation.

When $y$ is an explicit function of three rectangular co-ordinates, these things are true:

1st. The developement contains no quantities except what are found in $y$. The two expressions are entirely equivalent, being in reality the same quantities differently arranged.

2dly. When $y$ is a finite expression, the developement will consist of a finite number of terms; and when $y$ is a converging series of an infinite number of terms, the developement will be a like converging series. For, in the case of a converging series, we may approach to the value of $y$ as near as we please, by taking in a determinate number of the terms; and the developement of this portion of the series will likewise consist of a finite number of terms.

On the other hand, the properties that demand attention are very different, when we suppose that $y$ is not explicitly a function of three rectangular co-ordinates.

1st. The developement will always contain an infinite number of terms.

2dly. In most instances; and, more particularly, in the very general example that has been considered above; the terms of the developement will involve an infinite number of quantities which do not appear in the original function, and which are introduced merely in order to give the developement its peculiar form.

The original function and the whole infinite series of which the developement consists, may be represented by this equation, viz.

$$y = y + \mathrm{M} - \mathrm{M},$$

the right hand side, which stands in place of the developement, containing all the quantities in $y$, and besides an infinite number of other quantities, denoted by $+M$ and $-M$, which have opposite signs, and destroy one another. But this mutual destruction of the extraneous quantities will take place only when the totality of the series, comprehending its infinite number of terms, is taken into account. Any determinate number of terms of the developement will contain quantities not to be found in $y$; and, for aught that appears, the difference may have any given amount. No finite part of the developement can therefore properly be said to represent the proposed function. If we take a separate term, as $Q^{(6)}$, it is not extravagant to say that it may have nothing in common with the original expression. Nevertheless such a term is a necessary part of the series, in order to balance quantities that occur with opposite signs in other terms.

For the sake of illustration, suppose a spheroid of revolution determined by this equation, viz.

$$r = a\left\{1 + e\mu\sqrt{1-\mu^2}\right\};$$

$e$ being a small coefficient, and $\mu$ the cosine of an arc reckoned from one of the poles of revolution. In such a spheroid the greatest diameters will make an angle of $45^\circ$ with the equator, resembling the figure which the planet Saturn was, some years ago, supposed to have. In order to develope the variable part of the radius of the spheroid, that is $\mu\sqrt{1-\mu^2}$, in a series of quantities that satisfy the equation in partial fluxions, it is first necessary to expand $\sqrt{1-\mu^2}$; and the number of terms of the developement will therefore be infinite.

To the preceding equation let there be added the term

$f\mu \sin \varphi$; $\varphi$ denoting the variable angle that the circle on which the distance from the pole is reckoned, makes with a circle given by position; and the nature of the spheroid will be thus expressed, viz.

$$r = a\left\{1 + e\left(\mu\sqrt{1-\mu^2} + f\mu \sin \varphi\right)\right\}^{\frac{1}{2}}.$$

In this case the quantity to be developed must be put under this form, viz.

$$\mu\sqrt{1-\mu^2} + \frac{f\mu}{\sqrt{1-\mu^2}}\sqrt{1-\mu^2}\sin\varphi :$$

and the developement will not only consist of an infinite number of terms, but these terms will contain an infinite number of quantities which arise from the expansion of the radical in the denominator, and which are not to be found in the original function.

There is therefore a real distinction to be made between the two cases when $y$ is an explicit function of three rectangular co-ordinates, and when it is not. A method of calculation which is clear, exact and elegant, when it is confined to the first case, becomes clouded with obscurity, if not merely symbolical, when it is extended to the other case. To say the least, there are certainly great difficulties which are not explained; and if there be any geometers who hesitate, and have doubts, they are not without their excuse, and ought not to be entirely condemned.

2. We come next to consider the differential equation that takes place at the surface of a spheroid. Of this equation, three demonstrations have been published; one, in the second chapter of the third book of the *Mecanique Celeste*,* another by the same author, not precisely the same with the former,

* Tom. II. p. 18.

but similar to it, in a memoir read to the Academy of Sciences in 1818; and a third by M. Poisson, in an interesting and profound memoir on the distribution of heat in solid bodies. The two last demonstrations are fundamentally the same; but as M. Poisson has stated the reasoning more fully, and fixed the sense of the proof more precisely, I wish to refer to his memoir. One observation it is proper to make, which is, that in the integration by which the differential equation is proved, the function expressing the thickness of the molecule is considered as invariable, or is treated as a constant quantity. It is essential to attend to this remark, which in reality affords the clue necessary to unravel what is mysterious in this investigation.

In order to acquire a distinct notion of the meaning of the differential equation in the sense in which it is demonstrated, conceive the surface of the earth, perfectly smooth and spherical, to be covered with circles, we shall say, of a thousand yards radius each. The circles may either touch one another and cover the whole surface of the earth; or they may cover it partially only, and with any interruptions that can be imagined: conceive also that a mass of matter, or molecule, is placed within every circle; the thicknesses of the molecules being entirely arbitrary, and subject to no law of variation or restriction whatever, excepting that they are quantities of inconsiderable magnitude when compared with the radius of the sphere. These things being supposed, the differential equation will be separately true of every one of the molecules.

Let now the whole surface of the earth, or any portion of it, be covered with molecules, the thickness varying according

to a particular law, or being expressed by some function of the arcs that determine the position of a molecule: the differential equation will be true of all these molecules. But it will be equally true of them, if the thickness be entirely arbitrary, and subject to no law of variation. It is true, in reality, of each molecule taken in an insulated manner, and because its thickness is some determinate quantity. How then can such an equation be a fit means of proving that the thickness varies in one way rather than another, or that it comes under a particular developement?

To consider this matter more particularly, let $y=f(\theta,\phi)$ denote, as before, the thickness of the molecule; and put,

$$y'=f(\theta',\phi'),$$
$$\gamma=\cos\theta\cos\theta'+\sin\theta\sin\theta'\cos(\phi-\phi'),$$
$$\rho=\sqrt{\gamma^2-2r\alpha\,.\,\gamma+\alpha^2},$$

$a$ being less than $r$: then $\pi$ denoting the semi-circumference to the radius 1, the differential equation at the surface is what the following formula becomes in the particular case of $r=a$, viz.

$$y=\frac{r}{4\pi}\cdot\iint\left\{\frac{1}{r}+2a\frac{d.\frac{1}{\rho}}{d\alpha}\right\}y'\sin\theta'\,d\theta'\,d\phi';$$

or, by substituting the value of $\rho$,

$$y=\frac{1}{r\pi}\iint\frac{(r^2-\alpha^2)\,y'\sin\theta'\,d\theta'\,d\phi'}{\left(r^2-2r\alpha\gamma+\alpha^2\right)^{\frac{3}{2}}};\qquad\text{(A)}$$

the integral being taken between the limits $\theta'=0$, $\phi'=0$ and $\theta'=\pi$, $\phi'=2\pi$, and making $\alpha=r$, after the integration.

Now, when $r=a$, $r^2-\alpha^2=0$; and in this case all the elements of the integral are evanescent, unless in the particular circumstances when the denominator is evanescent, or when

$\gamma = 1$; which can happen only when $\theta' = \theta$, and $\phi' = \phi$. If therefore we suppose $r^2 - a^2$ to be indefinitely small, the whole value of the integral will be obtained by extending the integration to such values of $\theta'$ and $\phi'$ as differ indefinitely little from $\theta$ and $\phi$. But when $\theta'$ and $\phi'$ differ indefinitely little from $\theta$ and $\phi$, $\gamma'$ or $f(\theta', \phi')$, will differ indefinitely little from $\gamma$, or $f(\theta, \phi)$: and hence it follows that, in the whole extent of the integral, we may consider $\gamma'$ as constant and equal to $\gamma$. We have therefore to prove the truth of this formula, viz.

$$y = \frac{\gamma r}{4\pi} \cdot \iint \frac{(r^2 - a^2) \sin \theta' \, d\theta' \, d\phi'}{(r^2 - 2r\alpha\gamma + a^2)^{\frac{3}{2}}},$$

between the limits $\theta' = 0$, $\phi' = 0$, and $\theta' = \pi$, $\phi' = 2\pi$, in the particular case of $a = r$.

The two arcs $\theta$, $\theta'$ and the arc of which $\gamma$ is the cosine, are the three sides of a spherical triangle; $\phi - \phi'$ is the angle opposite to the last arc; and if $\psi - \psi'$ denote the angle opposite to $\theta'$, the element of the spherical surface will be equally expressed by $\sin \theta' \, d\theta' \, d\phi'$, or $d\phi' d. \cos \theta$, and by $d\psi' d\gamma$: wherefore we have to integrate this formula, viz.

$$y = \frac{\gamma r}{4\pi} \iint \frac{(r^2 - a^2) \cdot d\psi' d\gamma}{(r^2 - 2r\alpha\gamma + a^2)^{\frac{3}{2}}}.$$

Now integrate between the limits $\psi' = 0$ and $\psi' = 2\pi$: then

$$y = \frac{\gamma r}{2} \int \frac{(r^2 - a^2) \, d\gamma}{(r^2 - 2r\alpha\gamma + a^2)^{\frac{3}{2}}};$$

integrate again, and

$$y = \frac{\gamma}{2\alpha} \cdot \frac{r^2 - a^2}{\sqrt{r^2 - 2r\alpha\gamma + a^2}};$$

then take this integral between the limits $\gamma = +1$, and $\gamma = -1$; and

$$y = \frac{\gamma}{2\alpha} \cdot \left\{ \frac{r^2 - a^2}{\sqrt{r^2 - 2r\alpha}} - \frac{r^2 - a^2}{r + a} \right\},$$

which equation is true when we make $r = a$. This analysis is equivalent to the demonstration of M. Poisson. Whatever may be thought of the reasoning, it cannot be denied that, in both processes, $y'$ is in fact treated as a constant quantity. The equation is true of each individual molecule taken separately, and merely because its thickness has some determinate value. Such a demonstration cannot therefore be employed to prove that the thickness of a series of molecules covering the surface of a sphere, or a part of that surface, follows a certain law of variation, or comes under a particular developement.

But a legitimate process of reasoning requires that, in the formula (A), while $a$ represents any determinate quantity less than $r$, $y'$ be considered as a function of the variable quantities $\sin\theta'$, $\cos\theta'$, $\sin\varphi'$, $\cos\varphi'$; and likewise that the integration be extended to the whole surface of the sphere, or to that part of it covered with the related molecules; after which the true value of the formula will be obtained by making $a = r$. The whole system of molecules being comprehended in the result, we may thence deduce, by a reverse process, the law according to which their thickness must vary, in order to produce that result. Now the integration here spoken of, cannot be executed, unless in the case when $y'$ is explicitly a function of three rectangular co-ordinates. It is therefore only in this case that the differential equation can be considered as rigorously proved; and it is remarkable, that, when we seek from that equation the developement of $y'$, it always comes out in a function of three rectangular co-ordinates.

When $y'$ is not explicitly a function of three rectangular

co-ordinates, the formula (A) cannot be integrated. And, perhaps, what is now said, is alone sufficient to show that, in this case, some modification takes place, which it were desirable to have fully explained. On attempting to transform $y'$ into an expression containing $\gamma$, $\sqrt{1-\gamma^2}$, $\sin\psi'$, $\cos\psi'$ in place of $\cos\theta'$, $\sin\theta'$, $\sin\varphi'$, $\cos\varphi'$, the powers of $\sqrt{1-\gamma^2}$ make their appearance as divisors; and hence it is to be feared that the integral will be infinite at the limits; which circumstance would make it impossible to conclude with certainty what the value sought will become in the particular case of $a = r$. But it would be of no utility to seek a strict demonstration of the differential equation: because in reality the method, when it is extended to all functions of two variable arcs, is independent of that equation, being derived from this proposition, that every such expression is either explicitly a function of three rectangular co-ordinates, or may be transformed into one. The developement in question may always be found, as has been shown, by the rules of algebra; and the differential equation is wanted neither for proving the possibility of the developement, nor for calculating its terms. But in this plainer way of considering the matter, it appears that the developement does not represent the given expression $y'$, when that expression is not an explicit function of three rectangular co-ordinates, in the same sense that it does when it is such a function. There is, therefore, a difficulty left unexplained; and we may be permitted to doubt, whether so important a part of the celestial mechanics, as that regarding the figure of the planets, rests, with sufficient evidence, on the doctrine laid down concerning the generality of the developement.

The observations that have been made, relate only to the foundation of the method in the *Mecanique Celeste*, and do not touch upon the general scope of the analysis, which is deserving of every praise. It is natural to think, that the theory of the figure of the planets would be placed on a firmer basis, if it were deduced directly from the general principles of the case, than when it is made to depend on a nice, and somewhat uncertain point of analysis. To hazard a conjecture suggested in the course of writing this paper, the theory will probably be found to hinge on this proposition, that a spheroid, whether homogeneous or heterogeneous, cannot be in equilibrium by means of a rotatory motion about an axis, and the joint effect of the attraction of its own particles, and of the other bodies of the system, unless its radius be a function of three rectangular co-ordinates. If this proposition were clearly and rigorously demonstrated, the analysis of LAPLACE, in changing the ground on which it is built, would require little or no alteration in other respects.

Dec. 22, 1821.

## XIII. *On the late extraordinary depression of the Barometer.* By Luke Howard, *Esq. F.R.S.*

Read January 24, 1822.

The quicksilver having fallen to a lower point in the barometer in the course of last month than any person, probably, remembers to have seen it at, in the neighbourhood of London, a short account of the circumstances may, perhaps, not be unacceptable to the Royal Society.

On the evening of December 24, I found the barometer at 28.20 in. the wind being moderate at S.E., with steady rain, the temp. without, at 8 p.m. 45°. Water boiled freely at 210°. Finding the depression still to continue, I took a portable barometer, on Sir H. Englefield's construction, and having ascertained its height to be, at 11 p.m., 27.96 in., I set it up in my chamber on the first floor. At 3 a.m. the 25th, this instrument gave 27.83 in., and I have reason to think it did not go much lower: the rain had ceased early in the night, and it had become somewhat star-light, with a calm air, and hazy cirrostrati above: soon after five, however, the wind rose again, bringing some rain, apparently from N.W., but there was no tempest that I had opportunity to observe, though it might have blown hard during the few hours I slept. The pencil of my clock barometer travelled precisely to two-tenths below the bottom of the scale, having made a continuous downward sweep of nearly an inch and four-tenths in 24 hours: it appears to have turned to rise

abruptly, and by 8 a. m. was again on the point of passing 28 inches. In the 24 hours *preceding* this time, there had fallen eight tenths of an inch of rain; in the 24 hours *following* it there fell none, nor was the wind, which blew from S.W., at all strong; indeed it was calm all the middle part of the day, with sunshine and cirrus above: evaporation was very perceptible, and the night, up to 10 p. m. starlight. The barometer, at 8 p. m. the 25th, was at 28.40 in. In the early morning of the 27th, not having yet reached 29 in., it turned to fall again, with the wind at S. and S.W., after S.E.: we had again some heavy rain with hail about noon, and by midnight the quicksilver reached 28.07, or .06 in., where it stood, or rather made minute oscillations, *during the* 12 *hours following*, a thing I should scarcely have thought possible in our climate.

It was stormy, with much rain, and cloudy during most of this interval; but at noon on the 29th, and from the above-mentioned very low point, the decisive rise began; which proceeding in a bold uninterrupted curve into the afternoon of the 31st, the quicksilver once more touched upon 30 inches, with the winds northerly, and moderate; and the year went out with fine weather.

Such were the principal circumstances which met my notice in a depression of the barometer, to which I find no parallel, for London, in the whole Meteorological Annals of the Society. Let us, however, now advert to a case or two which seem to have approached to it. BARKER, of Lyndon, gives the following monthly minima, viz. 1782, April, 28.09 in.; 1783, February, 28.08; and March, 27.88 in. (Philosophical Transactions, Vol. LXXIII., p. 242, and LXXIV.,

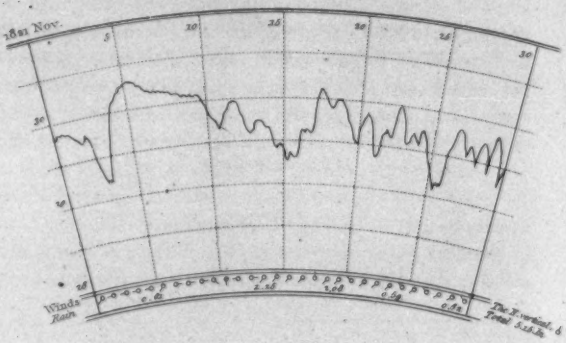
p. 283.) Now, the two latter occurred during the dreadful earthquakes in Calabria, of which we have a record in the Transactions; and I believe the barometer was noted to be extremely low, about that time, in various distant parts of England; but a comparison of the Society's Register is here precluded by a chasm of several years continuance. I have no doubt, however, from the general appearance of the means in the Lyndon Register, that the barometer there stood commonly some tenths lower than that at Somerset house. With respect to my own, I found yesterday, when the quicksilver was but little above 30 in., that my portable barometer exceeded that at Somerset House, when placed by its side, by 0.05 in., which was likewise, as nearly as I could judge, the difference in excess from my clock barometer. The latter therefore agrees very nearly, in this part of the scale at least, with the barometer registered in the Transactions.

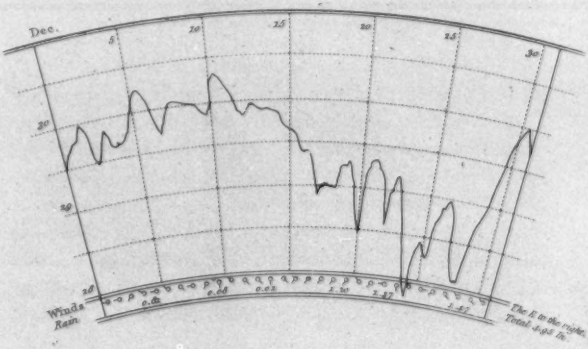
I annex to this paper a diagram, traced from the variation on the face of my clock, for the two latter months of 1821, the scale being three quarters to an inch, (Pl. XIII.) placing at bottom the amount of rain in each successive five days, and the winds, so far as may serve to show their succession. It will be seen that this great depression was preceded by abrupt changes, fluctuating for 30 days, chiefly between 29.5 and 30 inches, during a continuance of stormy weather; and that the depression itself was 14 or 15 days in progress, from the point of 30 inches, to that from which it finally rose in three days.

The rain for these two months is 10.10 inches, a quantity without precedent in the same space of time at London: that is to say, without one on record. BARKER gives, however,

for "April, 1782, 6.125 in.; and for "May, 5.722 in." at Lyndon; yet the South Lambeth table, given along with his own, exhibits but 6.24 in. for these two months; and states 6.88 in. for the seventh month (July), following, where he has but 2.70 in. I am almost at a loss for an apology to the Society, for having in my last paper anticipated, on the strength of a single analogy, a *dry* year for 1821, the fact being, that there has fallen at Tottenham, in the whole year, no less than 33.84 inches. It seems as if, with all our anxiety to pass the stream of uncertainty in this science, we must give over making the wooden bridges of conjecture, and wait till we can accumulate more solid materials.

*Tottenham Green,*
*First Month 10th, 1822.*




*Autographic Curve of the Variations of the Barometer at Tottenham, in the Months of November and December, 1821.*

## XIV. *On the anomalous magnetic action of hot iron between the white and blood-red heat.* By PETER BARLOW, *Esq. of the Royal Military Academy. Communicated by Major* THOMAS COLBY, *of the Royal Engineers, F. R. S.*

Read January 24, 1822.

IN consequence of certain theoretical results relative to the magnetic action of iron, obtained by Mr. CHARLES BONNYCASTLE, I was desirous of ascertaining the relative attraction which different species of iron and steel had for the magnet; and with this view I procured two bars of each of the following descriptions of metal, 24 inches in length, and 1 inch and a quarter square, which being placed successively in the direction of the dip, at a certain distance from the compass, the disturbance occasioned by each was carefully noted; first with one end upwards, and then with the other; and assuming the tangents of the angles as the measure of the disturbing power, I obtained the following specific results, viz.

| | Mag. Pow. | | Mag. Pow. |
|---|---|---|---|
| Malleable iron - - | 100 | Shear steel soft - - | 66 |
| Cast iron - - - | 48 | ——— hard - - | 58 |
| Blistered steel soft - | 67 | Cast steel soft - - | 74 |
| ——— hard - | 58 | ——— hard - - | 49 |

As it was obvious from these experiments, that the softer the iron the greater was its power, and the contrary, I was desirous of determining how nearly these different kinds of metal would approximate towards each other in their

magnetic action, when rendered perfectly soft by being heated in a furnace. With this view, bars of equal size of cast iron, malleable iron, shear steel, &c. were rendered white hot, and being placed in the direction of the dip, as before, their powers, as was anticipated, agreed nearly with each other; but still the cast iron, which was weakest while the metal was cold, exceeded a little in power all the others when hot, and the malleable iron which had the greatest power cold, had the least when hot; but the difference was not very great, and might probably arise from some accidental circumstance. While carrying on these experiments, it had been observed, both by Mr. BONNYCASTLE and myself, that between the white heat of the metal, when all magnetic action was lost, and the blood-red heat, at which it was the strongest, there was an intermediate state in which the iron attracted the needle the contrary way to what it did when it was cold, viz. if the bar and compass were so situated that the *north* end of the needle was drawn towards it when cold, the *south* end was attracted during the interval above alluded to, or while the iron was passing through the shades of colour denoted by the workman the bright red and red heat.

As this anomalous action had never before been noticed, I was desirous of examining it a little more particularly, and with the assistance of Mr. BONNYCASTLE, the following series of experiments were performed, wholly directed to this inquiry. Before entering upon the detail, however, it may not be amiss to notice those results which have hitherto been obtained relative to the magnetic action of heated iron; and to show how the contradictory statements, that we find on the subject, may be reconciled with each other. For example: we

find it stated in NEWTON's optics, that red hot iron has no magnetic property; while Father KIRCHER asserts, that the magnet will attract red hot iron as well as cold, (" de Magnete" lib. 1). Again, in Vol. XVIII. No. 214, Phil. Trans. it is stated, that hot iron not only has an attraction for the magnet, but that its power is increased by the heat; and these assertions have been repeated by many other authors, each supposing that his results were at variance with the other.

M. CAVALLO seems to have been the first writer, who was fully aware that these contradictory statements arose from the observations being made with the iron at different degrees of heat. He found, that although iron at the red heat had a greater power over the magnet than when cold, yet, at the white heat, it had a less; but he says he is still unable to decide, whether all the magnetic power is intirely lost at the white heat. (CAVALLO on Magnetism, p. 312.) More recent experiments on this subject are also recorded in Vol. IX. Part I. of the Transactions of the Royal Society of Edinburgh, by WILLIAM SCORESBY, Esq. But even here it does not appear that this Gentleman was aware of the total loss of power at a certain temperature; for he observes, (after showing that iron red hot has a greater power than when cold) " The contrary to this has, I think, been generally asserted:" from which it would seem, that he had not heated his iron to a sufficient degree to detect the non-action at the white heat.

Notwithstanding therefore all the experiments that have been made, it is pretty evident from the above remarks, that considerable uncertainty still hangs over the results; arising, without doubt, from the want of proper conveniences for heating bars of sufficient size, and to a proper degree of intensity,

whereby one author has noticed one fact, and another a different one, without being aware how much depended upon a very slight change in the temperature of the iron.

On these grounds therefore it is presumed, that the following experiments would be entitled to some notice, as they serve to reconcile all these apparently contradictory statements; but the principal reason which has induced me to lay them before the Royal Society is, the anomalous action which they have been the means of discovering, while the iron passes through the shades of bright red and red, already alluded to in the preceding part of this paper, and which, to the best of my knowledge, has never been noticed by any author.

*Experiments on the anomalous attraction of heated iron which takes place while the metal retains the bright red and red heat.*

I have already observed, that this anomalous action was noticed while we were pursuing other experiments, and that those which follow, were wholly directed to an examination of these irregularities.

In our first experiment, the compass was placed nearly west of the bar, rather below its upper extremity, and distant from it about $6\frac{1}{4}$ inches. At the white heat the attraction of the iron was lost; and at the blood red heat we had 70° of deviation in the needle; but that intermediate action we were searching after did not appear; at least it was by no means so obvious as we had noticed it in our preceding experiments.

The position of the bar and compass was not however quite the same as before; we therefore raised the support of the bar

about 4 inches, by which means its upper extremity was the same height above the compass, and on repeating the experiment with the bar thus placed, we obtained an obvious deviation of the south end of the needle towards the iron of $4\frac{1}{2}°$, which remained fixed about two minutes.

Having gained this by raising the bar 4 inches, we now raised it 6 inches, and on applying it in this place, we obtained a deviation of $10\frac{1}{2}°$, which remained fixed about the same time as before; when the needle suddenly yielded to the natural magnetic power of the iron, and obtained almost instantaneously a deviation of 81° the opposite way.

It was thus rendered obvious, that the quantity of negative attraction at the red heat, depended upon the height or depth of the centre of the bar from the compass; and as the natural effect of the cold iron was changed by placing the compass below the centre of the bar, the question which naturally suggested itself was, will the negative attraction also change? To decide this point, we lowered our compass to within 6 inches of the bottom of the bar; in which position the cold iron necessarily attracted the south end of the needle, and produced a deviation of 21°. Upon heating the bar, we found, as usual, all its power upon the needle cease at the white heat; but as this subsided into the bright red, the negative attraction began to manifest itself, and it soon amounted to $10\frac{1}{2}°$; the north end of the needle being attracted towards the iron. Here it remained stationary a short time, and then gradually returned, first due north, and ultimately to 70° 30′ on the opposite side.

Having made these preliminary experiments, I was anxious to undertake a regular series, hoping by this means to be

able to reduce this species of action to some fixed principle; for it will have been observed, from what is stated above, that the negative attraction appeared to increase from each extremity of the bar towards its middle; whereas the positive or natural action of the iron decreases in the like cases, and (passing through zero in the plane of no attraction) has its quality of attraction different when placed towards the upper or lower extremity of the bar.

The negative attraction has also the same change of character in the upper and lower extremity of the bar; but as it increases towards the middle, it appeared to pass through a maximum to arrive at that change, which seemed wholly inexplicable; and I must acknowledge that, after all the experiments I have made, it still remains so. It is at all events certain, that the least change of position of the compass when near the centre of the bar, changes altogether the quantity and quality of this negative action.

In the experiments detailed in the following table, I used four different bars, each 25 inches long, and $1\frac{1}{4}$ inch square; two of them of cast iron, denoted in the first column by C. B, No. 1; C. B, No. 2; and two of malleable iron, denoted by M. B, No. 1, and M. B, No. 2.

I had also two other bars, one of cast and one of malleable iron, of the same dimensions, which were not heated, but kept as standards for determining the quantity of cold attraction, as this could not safely be done by the bars used in the experiments after being so repeatedly heated.

The time employed in each experiment was about a quarter of an hour: the white heat commonly remained about 3 minutes, when the negative attraction commenced; this

lasted about two minutes more, when the usual attraction took place: this sometimes arrived at its maximum very rapidly, but at others it proceeded increasing very gradually; and commonly within the time stated above, the needle had been found perfectly stationary.

In the table, to avoid confusion, that attraction which took place according to the known laws of cold iron is marked *plus*, whichever end of the needle approached the iron, and the opposite attraction is marked *minus*. For example, when the compass is above the centre of the bar, the north end of the needle should be drawn towards the iron, but when the compass is below the centre, the south end should approach the iron; these therefore are both marked *plus*, and the contrary attraction at the red heat is marked *minus*.

## TABLE,

*Showing the effect of iron on the compass needle at different degrees of heat.*

| No. | Description of bar. | Height or depth of centre of bar from compass. | Distance of bar from compass. | Position of compass. | Effect Cold. | Effect White Heat. | Effect Red Heat. | Effect Blood red Heat. | REMARKS. |
|---|---|---|---|---|---|---|---|---|---|
| | | Inch. | Inch. | | ° ′ | ° ′ | ° ′ | ° ′ | |
| 1 | C. B. No. 1. | 0.0 | 6.0 | S. 80 W. | + 0 0 | 0 0 | — 17 0 | 0 0 | South end drawn to the bar at red heat. |
| 2 | M. B. No. 2. | 4.5 below. | 6.0 | ditto. | +30 0 | ditto. | 0 0 | +45 0 | |
| 3 | C. B. No. 2. | 4.5 below. | 6.0 | ditto. | +18 0 | ditto. | 0 0 | +49 0 | |
| 4 | M. B. No. 1. | ditto. | 6.0 | ditto. | +29 30 | ditto. | — 12 0 | +44 0 | |
| 5 | ditto. | 13 below. | 6.0 | ditto. | Not obs. | ditto. | 0 0 | +52 0 | |
| 6 | ditto. | 4.5 below. | 6.0 | N. 80 W. | ditto. | ditto. | — 12 30 | +70 0 | This bar being left standing, it attracted the same three days after. |
| 7 | ditto. | 4.5 above. | 6.0 | S. 80 W. | ditto. | ditto. | — 12 30 | +30 0 | |
| 8 | ditto. | ditto. | 6.0 | ditto. | ditto. | ditto. | 0 0 | +25 0 | The needle suspected to touch the box. |
| 9 | ditto. | ditto. | 6.0 | ditto. | ditto. | ditto. | — 19 0 | +30 0 | |
| 10 | ditto. | 1.0 above. | 6.0 | ditto. | ditto. | ditto. | — 15 0 | + 4 0 | |
| 11 | M. B. No. 2. | 12.5 below. | 8.5 | N. 80 W. | +29 30 | ditto. | 0 0 | +37 30 | Observed at the same time with two compasses. |
| 12 | ditto. | ditto. | 8.5 | N. 80 E. | +30 0 | ditto. | 0 0 | +41 0 | |
| 13 | C. B. No. 1. | 12.5 below. | 8.5 | N. 80 W. | +16 0 | ditto. | 0 0 | +42 30 | Ditto. |
| 14 | ditto. | ditto. | 8.5 | N. 80 E. | +15 30 | ditto. | 0 0 | +47 30 | |
| 15 | M. B. No. 2. | 9.0 below. | 8.5 | N. 80 W. | +28 30 | ditto. | — 1 0 | +39 30 | Ditto. |
| 16 | ditto. | ditto. | 8.5 | N. 80 E. | +29 30 | ditto. | — 1 30 | +42 0 | |
| 17 | C. B. No. 1. | 9.0 below. | 8.5 | N. 80 W. | +15 45 | ditto. | — 1 30 | +45 0 | Ditto. |
| 18 | ditto. | ditto. | 8.5 | N. 80 E. | +16 0 | ditto. | — 1 30 | 49 0 | |
| 19 | M. B. No. 2. | 6.0 below. | 8.5 | N. 80 W. | +25 0 | ditto. | — 3 0 | +32 30 | Ditto. |
| 20 | ditto. | ditto. | 8.5 | N. 80 E. | +26 0 | ditto. | — 3 30 | +33 0 | |
| 21 | C. B. No. 1. | 6.0 below. | 8.5 | N. 80 W. | +11 30 | ditto. | — 3 30 | +36 30 | Ditto. |
| 22 | ditto. | ditto. | 8.5 | N. 80 E. | +13 0 | ditto. | Not obs. | +36 30 | |
| 23 | M. B. No. 2. | 3.0 below. | 6.0 | S. 80 E. | + 8 0 | ditto. | — 21 30 | Not obs. | Ditto. |
| 24 | ditto. | ditto. | 6.0 | N. 45 W. | Not obs. | ditto. | — 25 30 | +25 30 | |
| 25 | M. B. No. 1. | 0.0 | 6.0 | ditto. | 0 0 | ditto. | — 40 0 | 0 0 | North end drawn to the bar at red heat. |
| 26 | M. B. No. 2. | 1.0 above. | 5.3 | N. 60 W. | + 2 0 | ditto. | — 4 30 | + 5 30 | Both attractions very gradual. |
| 27 | M. B. No. 1. | ditto. | 5.3 | ditto. | Not obs. | ditto. | — 12 30 | + 5 30 | Passed suddenly to 12½°, but returned immediately. |
| 28 | M. B. No. 2. | 9.0 above. | 6.0 | N. 85 E. | +47 30 | ditto. | — 2 30 | +60 0 | Attractions gradual. |
| 29 | M. B. No. 1. | ditto. | 6.0 | ditto. | +47 30 | ditto. | — 2 30 | +60 0 | Ditto. |
| 30 | M. B. No. 2. | 1.0 below. | 5.5 | N. 45 W. | Not obs. | ditto. | — 55 0 | + 5 45 | Negative attraction rather sudden. |
| 31 | M. B. No. 1. | 4.5 above. | 7.0 | N. 75 E. | ditto. | ditto. | — 2 30 | +33 30 | Motion of needle very slow. |
| 32 | M. B. No. 2. | 1.7 below. | 5.5 | N. 45 W. | ditto. | ditto. | +100 0 | +13 30 | 100° very sudden, returned immediately. |
| 33 | M. B. No. 1. | 1.7 above. | 5.5 | ditto. | ditto. | ditto. | — 26 0 | +13 30 | Both attractions gradual. |
| 34 | M. B. No. 2. | 1.7 above. | 5.5 | ditto. | ditto. | ditto. | + 30 0 | +13 30 | The same as No. 32; both anomalous. |
| 35 | M. B. No. 1. | 4.5 above. | 6.0 | N. 55 E. | ditto. | ditto. | — 5 30 | +35 30 | Attractions very gradual. |
| 36 | M. B. No. 2. | ditto. | 6.0 | ditto. | ditto. | ditto. | — 0 0 | +35 30 | |
| 37 | M. B. No. 1. | 0.0 | 4.7 | West. | + 3 30 | ditto. | — 50 0 | + 8 0 | Motion regular, but quick. |
| 38 | M. B. No. 2. | 0.0 | 4.7 | North. | 0 0 | ditto. | 0 0 | 0 0 | No motion in the needle. |

It should be observed, that all the above experiments were made with the bars inclined in the direction of the dipping needle, or nearly in that direction, and it will be seen that the negative attraction was the greatest where the natural attraction was the least; that is, opposite the middle of the bar, or in the plane of no attraction. I was led, therefore, to make a few experiments with the bar inclined at right angles to its former position, but the results were by no means so strongly marked as in the preceding experiments: we always found a certain quantity of negative attraction, but it was very inconsiderable, never amounting to more than 2½°.

I also made one experiment with an iron 24lb. ball, but the heat was too intense to make any very accurate observation. The numbers obtained were

Cold attraction +13° 30′. White heat 0° 0′.

Red heat −3° 30′. Blood-red heat +19° 30′.

It may be proper also to state, that, being doubtful how far the heat itself, independent of the iron, might be the cause of the anomalous action above described, I procured two copper bolts of rather larger dimensions than my iron bars, and had them heated to the greatest degree that metal would bear; but on applying them to the compass, no motion whatever could be discovered in the needle.

The only probable explanation which I can offer by way of accounting for these anomalies, is, that the iron cooling faster towards its extremities than towards its centre, a part of the bar will become magnetic before the other part, and thereby cause a different species of attraction; but I must acknowledge, that this will not satisfactorily explain all the observed

phenomena. The results, however, are stated precisely as they were noted during the experiments, and others more competent than myself will probably be able to deduce the theory of them.

## XV. *Observations for ascertaining the length of the Pendulum at Madras in the East Indies, latitude 13° 4′ 9″,1 N. with the conclusions drawn from the same.* By JOHN GOLDINGHAM, *Esq. F. R. S.*

Read January 31, 1822.

THE object of the enquiry in this paper has been considered at all times one of interest and importance, and is particularly so at present, when investigations have been completed in Europe, by order of some of the governments there; such as, with reference to their accuracy, had never before been made in any quarter of the globe, so far as comes within my recollection. I had seen the details of Captain KATER's experiments in the Philosophical Transactions, and he also did me the favour to send me out a copy of his Paper. The simplicity and accuracy of the apparatus induced me to write to that Gentleman, requesting he would have the goodness to order a similar one to be sent to me. This request he not only most readily complied with, but made the experiments requisite for enabling me to draw the conclusions; and thence to form the comparison with the results obtained in Europe. The apparatus arrived in March, and I immediately set about fixing it; which, notwithstanding the little solid assistance to be obtained in an operation of this nature from workmen in this country, I was enabled to effect in a most satisfactory manner; and I am led to hope, these observations will not be deemed unworthy the attention of the learned in Europe.

The clock used in these experiments has a gridiron pendulum, the motion being given by a spring; the maker's name is HASWELL, and the works are of the best description: it was fixed to the north wall of the Observatory, which is of solid masonry two feet in thickness: the rate was ascertained by comparisons with the transit clock each day, at the commencement and conclusion of the experiments: the transit of the noon before the comparison, and that after, were used in finding this rate; so that four results were obtained from the two comparisons: the transit clock, which is an excellent time keeper, was regulated by transits of the sun and stars; the weather fortunately having been clear, both at noon and at night, during the time the experiments were making.

The first operation performed was that of making the weight of the clock pendulum black, and fixing the disc on the centre. This having been done, five blocks of seasoned teak-wood, each 3 inches in diameter and 7 in length, were prepared; the place above the clock for the frame, which was to support the pendulum, was then marked. This I did with great care and precaution: intersecting lines were drawn upon the wall to show the exact position of the centres of the blocks and of the screws for fastening the frame; holes $\frac{1}{4}$ inches in diameter and $10\frac{1}{2}$ in depth, (it being necessary to let the outer part of the blocks $3\frac{1}{2}$ inches within the surface of the wall, to bring the pendulum sufficiently near the clock case) were then made in the wall, and the blocks, coated with tar to preserve them from the white ants, were let in and firmly secured. The outer surfaces of the whole, which had previously been made smooth and level, being in

one plane. The frame, its two parts being firmly screwed together, was then placed, levelled by means of a spirit level, and fixed to the blocks in the firmest manner: the frame enclosing the agates was next put up, levelled, and screwed in its place, the Y's elevated, and the pendulum hung; the knife edges were then lowered upon the agates; when I had the satisfaction to find, from the precautions which I had taken, that the pendulum was most correctly in its place. In this distant part of the globe, there is an anxiety in handling and fixing any new apparatus which is not felt in England, where the maker of it is ready to give assistance, as well as to repair any damage that may chance to have been done: here, little or no assistance can be obtained; and if the use of any part of the apparatus should be mistaken, and the part forced into a wrong place, the injury may be fatal to the experiments, as it cannot be repaired here; it therefore affords no small gratification when an instrument is firmly secured, uninjured, in its proper position.

The pendulum is precisely the same, in all its parts, as that used by Captain Kater at the different stations of the Trigonometrical Survey of England, and which he has fully described in the Philosophical Transactions for 1819. Any farther description therefore of its construction, will here be unnecessary.

The next operation was to fix the arc for measuring the vibrations. The clock-case was of handsome mahogany enriched with projecting mouldings, with the door in front of plate glass. The mouldings kept the pendulum at too great a distance from the part of the case where the arc could otherwise have been fastened, and it became necessary to

have a support in front of the case. I therefore had a solid stand of teak wood made, similar to that for supporting the telescope, the inner part cut out to the form of the mouldings of the clock-case, so that it fitted perfectly close to it; in this position it was screwed to the floor; the ends for the supports of the arc were then let in, and secured to the top of the stand, and the arc fixed in its proper place, with reference to the extreme point of the pendulum. The floor outside of this apparatus was then separated from the part of the floor which supported it, to prevent any shake by persons moving about within the building.

The small telescope containing the diaphragm was now fixed upon its stand, and screwed to the floor at the proper distance from the pendulum: this was about $9\frac{1}{2}$ feet. The telescope, and every other part of the apparatus, have been so fully described by Captain KATER in the paper published in the Philosophical Transactions, that I feel it unnecessary to be more particular here.*

While making the holes in the wall above the clock for the insertion of the blocks for supporting the frame, a great deal of dust would necessarily fall upon the clock-case; every part of the case where dust could penetrate was therefore filled up with wax, and several folds of cloth were afterwards secured over the whole of the case, so that it was hardly possible that any dust could penetrate to the works of the clock. After the frame was fixed, the cloth and wax were removed, and fresh oil applied to the works.

* The drawing [Pl. XIV] shows the inside of a part of the Observatory, the pendulum up, and the adjustment of the diaphragm making, preparatory to commencing the observations.

The clock was then set in motion. This was on the 22d of March, and the observations commenced two days afterwards.

The following is the mode pursued in making the observations.

The pendulum was lifted up from the Y's by myself and an assistant, and the knife edges wiped with a cloth saturated with oil. The pendulum was then replaced, and the Y's lowered, so that the knife edges rested upon the agates. The telescope was then adjusted (care being taken that the O on the arc of vibration coincided with the point of the slip), so that the edges of the slip were exactly embraced by the edges of the diaphragm. The height of the barometer, of the thermometer fixed near the middle of the pendulum, and that of the hygrometer, were taken and registered. The point of the slip at the end of the pendulum was then brought and kept by the hand to about 1°,3 upon the arc; and an instant before the pendulum of the clock was at its highest point on the same side, the hand was withdrawn, and the pendulum thereby allowed to vibrate freely. I stationed the head Bramin assistant* to take down the time, and the youngest Bramin assistant to count the clock, which he does with the greatest correctness. Having placed myself at the telescope, I found there was a sensible portion of time, more or less, as the arc of vibration was greater or smaller, between the disappearance of the disc behind the slip, and its reappearance; I therefore noticed the seconds, and parts of a second, when the disc disappeared, and also the instant when it

* The name of the head assistant is Senavassachary, and that of the other Terovencatachary.

again appeared, both which the Bramin put down; the mean of these I took as the true time of the coincidence, and registered it accordingly. These times I found could be accurately noted; and it is probable the mean of the two observations is generally correct to less than half a second. In this manner the times of the coincidences were observed. The thermometer often varying a good deal in a short time, I thought it right to take its height three times, at the third observation of each set, as well as the first and fifth. The barometer was observed at the end of each set, as well as at the beginning; and also the hygrometer, as mentioned above, at the beginning of the observations, and likewise at the end of those of each day; being desirous of seeing how much the atmosphere had changed in dryness, as well as in heat and weight; not that this was material, but it is satisfactory to know what change there actually was in the atmosphere during the time the observations were making. I now proceed to detail the observations.

Every observation taken is here given. As although in this as in similar cases, one feels better pleased with some observations than with others, yet I do not recollect more than two of these observations, which I felt dissatisfied with at the time, and that not in a sufficient degree to induce me to think of rejecting them.

The results, I trust, will prove how unnecessary it would have been to have rejected any of the observations.

## OBSERVATIONS.

FIRST SERIES.

| | h. | m. | Inch. |
|---|---|---|---|
| March 24th A. M. | 6 | 24 | 30,085 |
| | 7 | 12 | 30,101 |
| Mean | - | | 30,093 |

Rate of the Clock —0″,39.
Hygrometer 11°,5 dry.

| Temp. | Time of coincidence. | Arc of vibration. | Mean Arc. | Interval in seconds. | Number of vibrations. | Observed vibrations in 24 hours. | Correction for Arc. | For Temperature. | Vibrations in 24 hours. |
|---|---|---|---|---|---|---|---|---|---|
| ° | h. m. s. | ° | ° | ″ | | | + | + | |
| 81 | 6 23 44 | 1,15 | | | | | | | |
| | | | 1, 10 | 721,25 | 719,25 | 86160,42 | 1,983 | 4,687 | 86167,090 |
| | 35 45,25 | 1,05 | | | | | | | |
| | | | 1, 01 | 722,75 | 720,75 | 86160,91 | 1,671 | 4,750 | 86167,331 |
| 81,3 | 47 48 | 0,97 | | | | | | | |
| | | | 0,935 | 724 | 722 | 86161,33 | 1,432 | 4,793 | 86167,553 |
| | 59 52 | 0,88 | | | | | | | |
| | | | 0,835 | 723, 8 | 721, 8 | 86161,26 | 1,102 | 4,814 | 86167,216 |
| 81,4 | 7 11 55,8 | 0,79 | | | | | | | |
| 81,23 | Mean | | | | | | Rate of the Clock | | 86167,298 — 0,390 |
| | | | | | | | | | 86166,908 |

Rate of the Clock —0″,39 Barometer { 30,105 / 30,123 }
Mean - 30,114

| | h. | m. | s. | ° | ° | ″ | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 81,5 | 7 | 24 | 50,5 | 1,13 | | | | | | |
| | | | | | 1,065 | 722, 4 | 720, 4 | 86160,80 | 1,858 | 4,809 | 86167,467 |
| | | 36 | 52,9 | 1,00 | | | | | | | |
| | | | | | 0, 95 | 725, 7 | 723, 7 | 86161,88 | 1,479 | 4,915 | 86168,274 |
| 82 | | 48 | 58,6 | 0,90 | | | | | | | |
| | | | | | 0, 87 | 723,65 | 721,65 | 86161,21 | 1,240 | 5,152 | 86167,602 |
| | 8 | 1 | 2,25 | 0,84 | | | | | | | |
| | | | | | 0,795 | 723,75 | 721,75 | 86161,24 | 1,036 | 5,300 | 86167,576 |
| 82,7 | | 13 | 6,0 | 0,75 | | | | | | | |
| 81,73 | Mean | | | | | | | | Rate of the Clock | | 86167,729 —,390 |
| | | | | | | | | | | | 86167,339 |

Barometer { 30,127 / 30,134

Mean - 30,135

| Temp. | Time of coincidence. | Arc of vibration. | Mean Arc. | Interval in seconds. | Number of vibrations. | Observed vibrations in 24 hours. | Correction for Arc. | For Temperature. | Vibrations in 24 hours. |
|---|---|---|---|---|---|---|---|---|---|
| ° | h. m. s. | ° | ° | " | | | + | + | |
| 82,9 | 8 29 26,5 | 1,15 | | | | | | | |
| | 41 27,1 | 1,05 | 1,10 | 720, 6 | 718, 6 | 86160,20 | 1,983 | 5,512 | 86167,692 |
| | | | 1,00 | 725, 0 | 723, 0 | 86161,66 | 1,638 | 5,592 | 86168,888 |
| 83,4 | 53 32,1 | 0,95 | | | | | | | |
| | | | 0,91 | 722,65 | 720,65 | 86160,88 | 1,357 | 5,765 | 86167,995 |
| | 9 5 34,75 | 0,87 | | | | | | | |
| | | | 0,83 | 722,65 | 720,65 | 86160,88 | 1,129 | 5,956 | 86167,996 |
| 84,3 | 17 37,4 | 0,79 | | | | | | | |
| | | | | | | | | | 86168,135 |
| 83,53 | Mean | | | | | Rate of the Clock | | | — 0,390 |
| | | | | | | | | | 86167,745 |

Barometer { 30,129 / 30,140

Mean - 30,135

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | h. m. s. | ° | ° | " | | | + | + | |
| 84,5 | 9 33 39,25 | 1,11 | | | | | | | |
| | | | 1, 07 | 719,35 | 717,35 | 86159,78 | 1,876 | 6,188 | 86167,844 |
| | 45 38,6 | 1,03 | | | | | | | |
| | | | 0, 99 | 718,15 | 716,15 | 86159,38 | 1,605 | 6,290 | 86167,275 |
| 85 | 57 36,75 | 0,95 | | | | | | | |
| | | | 0,915 | 718,75 | 716,75 | 86159,58 | 1,372 | 6,345 | 86167,297 |
| | 10 9 35,5 | 0,88 | | | | | | | |
| | | | 0, 84 | 719, 5 | 717, 5 | 86159,83 | 1,156 | 6,345 | 86167,331 |
| 85 | 21 35,0 | 0,80 | | | | | | | |
| | | | | | | | | | 86167,437 |
| 84,83 | Mean | | | | | Rate of the Clock | | | — ,390 |
| | | | | | | | | | 86167,047 |

Hygrometer 13, dry — Barometer { 30,140 / 30,148 }

Mean — 30,141

| Temp. | Time of coincidence. | Arc of vibration. | Mean Arc. | Interval in seconds. | Number of vibrations | Observed vibrations in 24 hours. | Correction for Arc. | For Temperature. | Vibrations in 24 hours. |
|---|---|---|---|---|---|---|---|---|---|
| ° | h. m. s. | ° | ° | " | | | + | + | |
| 84,9 | 10 30 16,6 | 1,20 | | | | | | | |
| | | | 1,165 | 713,65 | 711,65 | 86157,86 | 2,224 | 6,315 | 86166,399 |
| | 42 10,25 | 1,13 | | | | | | | |
| | | | 1,085 | 715,25 | 713,25 | 86158,01 | 1,929 | 6,332 | 86166,654 |
| 85 | 54 5,5 | 1,04 | | | | | | | |
| | | | 1,015 | 717,0 | 715, 0 | 86159,00 | 1,688 | 6,345 | 86167,033 |
| | 11 6 2,5 | 0,99 | | | | | | | |
| | | | 0,945 | 715,65 | 713,65 | 86158,64 | 1,463 | 6,345 | 86166,348 |
| 85 | 17 58,15 | 0,90 | | | | | | | |
| | | | | | | | | | 86166,608 |
| 84,97 | Mean | | | | | Rate of the Clock | | | — ,390 |
| | | | | | | | | | 86166,218 |

March 25, A. M. — Barometer { 30,148 / 30,147 }

Clock losing 1",49 / Hygrometer 12°. dry — Mean — 30,145

| ° | h. m. s. | ° + | ° | " | | | + | + | |
|---|---|---|---|---|---|---|---|---|---|
| 80,3 | 6 14 0,25 | 1,24 | | | | | | | |
| | | | 1,205 | 717,5 | 715, 5 | 86159,16 | 2,379 | 4,433 | 86165,972 |
| | 25 57,75 | 1,17 | | | | | | | |
| | | | 1,130 | 720,25 | 718,25 | 86160,08 | 2,092 | 4,581 | 86166,753 |
| 81,0 | 37 58 | 1,09 | | | | | | | |
| | | | 1,055 | 720,5 | 718, 5 | 86160,03 | 1,826 | 4,674 | 86166,530 |
| | 49 58,5 | 1,02 | | | | | | | |
| | | | 0,980 | 722,6 | 720, 6 | 86160,86 | 1,574 | 4,716 | 86167,150 |
| 81,2 | 7 2 1,1 | 0,94 | | | | | | | |
| | | | | | | | | | 86166,601 |
| 80,83 | Mean | | | | | Rate of the Clock | | | — 1,490 |
| | | | | | | | | | 86165,111 |

End of the Experiments. Barometer { 30,147 / 30,161

Hygrometer 12°½ dry. Mean - 30,154

| Temp. | Time of coincidence. | Arc of vibration. | Mean Arc. | Interval in seconds. | Number of vibrations. | Observed vibrations in 24 hours. | Correction for Arc. | For Temperature. | Vibrations in 24 hours. |
|---|---|---|---|---|---|---|---|---|---|
| | h. m. s. | ° | ° | " | | | + | + | |
| 81,2 | 7 10 19,5 | 1,28 | | | | | | | |
| | | | 1,23 | 719,1 | 717,1 | 86159,70 | 2,479 | 4,780 | 86166,959 |
| | 22 18,6 | 1,18 | | | | | | | |
| | | | 1,125 | 722 | 720 | 86160,66 | 2,073 | 4,864 | 86167,597 |
| 81,6 | 34 20,6 | 1,07 | | | | | | | |
| | | | 1, 02 | 723 | 721 | 86160,99 | 1,705 | 4,949 | 86167,644 |
| | 46 23,6 | 0,97 | | | | | | | |
| | | | 0, 91 | 724,5 | 722,5 | 86161,49 | 1,357 | 5,245 | 86168,092 |
| 82 | 58 28,1 | 0,85 | | | | | | | |
| 81,6 | Mean | | | | | Rate of the Clock | | | 86167,573 — 1,490 |
| | | | | | | | | | 86166,083 |

March 26, P. M. Barometer { 30,132 / 30,138

Clock losing 1",91 } Hygrometer 15°,6 dry } Mean - 30,138

| | h. m. s. | ° | ° | " | | | + | + | |
|---|---|---|---|---|---|---|---|---|---|
| 84 | 4 58 37,1 | 1,20 | | | | | | | |
| | | | 1,15 | 716, 5 | 714, 5 | 86158,83 | 2,167 | 5,913 | 86166,910 |
| | 10 33,6 | 1,10 | | | | | | | |
| | | | 1,07 | 717,85 | 715,85 | 86159,18 | 1,876 | 5,888 | 86167,044 |
| 83,9 | 22 31,45 | 1,04 | | | | | | | |
| | | | 1,01 | 719,05 | 717,05 | 86159,68 | 1,671 | 5,837 | 86167,188 |
| | 34 30,5 | 0,98 | | | | | | | |
| | | | 0,94 | 720, | 718, 0 | 86160,00 | 1,448 | 5,753 | 86167,201 |
| 83,5 | 46 30,5 | 0,90 | | | | | | | |
| 83,8 | Mean | | | | | Rate of the Clock | | | 86167,086 — 1,910 |
| | | | | | | | | | 86165,176 |

March 26, A. M. Barometer { 30,149 / 30,150

Clock losing 2″,08 / Hygrometer 14°, dry. } Mean - 30,149

| Temp. | Time of coincidence. | Arc of vibration. | Mean Arc. | Interval in seconds. | Number of vibrations. | Observed vibrations in 24 hours. | Correction for Arc. | For Temperature. | Vibrations in 24 hours. |
|---|---|---|---|---|---|---|---|---|---|
| | h. m. s. | ° | ° | ″ | | | + | + | |
| 79,3 | 5 58 58,1 | 1,19 | | | | | | | |
| | | | 1, 14 | 723,27 | 721,27 | 86161,08 | 2,129 | 3,955 | 86167,164 |
| | 11 1,37 | 1,09 | | | | | | | |
| | | | 1,045 | 725,38 | 723,38 | 86161,70 | 1,789 | 3,997 | 86167,466 |
| 79,5 | 23 6,75 | 1,00 | | | | | | | |
| | | | 0,965 | 725, 5 | 723, 5 | 86161,81 | 1,526 | 4,048 | 86167,384 |
| | 35 12,25 | 0,93 | | | | | | | |
| | | | 0, 90 | 727, 2 | 725, 2 | 86162,37 | 1,327 | 4,116 | 86167,813 |
| | 47 19,45 | 0,87 | | | | | | | |
| 79,53 | Mean | | | | | Rate of the Clock | | | 86167,457 — 2,080 |
| | | | | | | | | | 86165,377 |

Hygrometer 13°,6 dry. Barometer { 30,150 / 30,178

Mean - 30,162

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | h. m. s. | ° | ° | ″ | | | + | + | |
| 79,8 | 6 56 30,62 | 1,29 | | | | | | | |
| | | | 1, 24 | 721,88 | 719,88 | 86161,63 | 2,519 | 4,264 | 86168,413 |
| | 7 8 32,5 | 1,19 | | | | | | | |
| | | | 1, 14 | 724, 0 | 722, 0 | 86161,32 | 2,129 | 4,496 | 86167,945 |
| 80,9 | 20 36,5 | 1,09 | | | | | | | |
| | | | 1,045 | 724,17 | 722,17 | 86161,38 | 1,789 | 4,653 | 86167,822 |
| | 32 40,67 | 1,00 | | | | | | | |
| | | | 0,965 | 725,33 | 723,33 | 86161,76 | 1,526 | 4,738 | 86168,024 |
| | 44 46, | 0,93 | | | | | | | |
| 80,67 | Mean | | | | | Rate of the Clock | | | 86168,031 — 2, 08 |
| | | | | | | | | | 86165,971 |

March 27, P. M. Barometer { 30,116 / 30,131

Clock losing 2″,06 / Hygrometer 20° dry. Mean - 30,123

| Temp. | Time of coincidence. | Arc of vibration. | Mean Arc. | Interval in seconds. | Number of vibrations. | Observed vibrations in 24 hours. | Correction for Arc. | For Temperature. | Vibrations in 24 hours. |
|---|---|---|---|---|---|---|---|---|---|
| | h. m. s. | ° | ° | ″ | | | + | + | |
| 84, 7 | 4 13 44,25 | 1,24 | | | | | | | |
| | | | 1, 20 | 715,87 | 713,87 | 86158,62 | 2,359 | 6,176 | 86167,155 |
| | 25 40,12 | 1,16 | | | | | | | |
| | | | 1, 12 | 716,51 | 714,51 | 86158,83 | 2,055 | 6,091 | 86166,976 |
| 84, 3 | 37 36,63 | 1,08 | | | | | | | |
| | | | 1,035 | 717,87 | 715,87 | 86159,29 | 1,755 | 6,028 | 86167,070 |
| | 49 34, 5 | 0,99 | | | | | | | |
| | | | 0,955 | 717,87 | 715,87 | 86159,28 | 1,494 | 5,985 | 86166,759 |
| 84, 1 | 5 1 32,37 | 0,92 | | | | | | | |
| 84,37 | Mean | | | | | | Mean of the Clock | | 86166,990 — 2,060 |
| | | | | | | | | | 86164,930 |

Hygrometer 19°,3 dry. Barometer { 30,131 / 30,087

Mean - 30,109

| | h. m. s. | ° | ° | ″ | | | + | + | |
|---|---|---|---|---|---|---|---|---|---|
| 84,1 | 5 10 14,75 | 1,28 | | | | | | | |
| | | | 1,235 | 716,50 | 714,50 | 86158,83 | 2,499 | 5,943 | 86167,272 |
| | 22 11,25 | 1,19 | | | | | | | |
| | | | 1, 14 | 718,50 | 716,50 | 86159,50 | 2,129 | 5,901 | 86167,530 |
| 83,9 | 34 9,75 | 1,09 | | | | | | | |
| | | | 1,045 | 718,87 | 716,87 | 86159,62 | 1,789 | 5 837 | 86167,246 |
| | 46 8,62 | 1,00 | | | | | | | |
| | | | 0, 96 | 720,63 | 718,63 | 86160,21 | 1, 51 | 5,753 | 86167,473 |
| 83,5 | 58 9,25 | 0,92 | | | | | | | |
| 83,83 | Mean | | | | | | Rate of the Clock | | 86167,380 — 2 060 |
| | | | | | | | | | 86165,320 |

March 29, P. M. Barometer { 30,084 / 30,113

Clock losing 1″,46 / Hygrometer 17°,7 dry. } Mean - 30,098

| Temp. | Time of coincidence. | Arc of vibration. | Mean Arc. | Interval in seconds. | Number of vibrations. | Observed vibrations in 24 hours. | Correction for Arc. | For Temperature. | Vibrations in 24 hours. |
|---|---|---|---|---|---|---|---|---|---|
| | h. m. s. | ° | ° | ″ | | | + | + | |
| 84,5 | 2 59 8 | 1,23 | | | | | | | |
| | | | 1,19 | 719,12 | 717,12 | 86159,71 | 2,320 | 6,112 | 86168,142 |
| | 3 11 7,12 | 1,15 | | | | | | | |
| | | | 1,11 | 720,88 | 718,88 | 86160,29 | 2,019 | 6,070 | 86168,389 |
| 84,3 | 23 8,0 | 1,07 | | | | | | | |
| | | | 1,02 | 723, 0 | 721, 0 | 86160,99 | 1,705 | 6,028 | 86168,723 |
| | 35 11,0 | 0,97 | | | | | | | |
| | | | 0,93 | 723,63 | 721,63 | 86161,20 | 1,417 | 5,985 | 86168,602 |
| 84,1 | 47 14,63 | 0,89 | | | | | | | |
| | | | | | | | | | 86168,464 |
| 84,3 | Mean | | | | | | Rate of the Clock | | — 1,460 |
| | | | | | | | | | 86167,004 |

Hygrometer 17°,7 dry. Barometer { 30,113 / 30,087

Mean - 30,100

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | h. m. s. | ° | ° | ″ | | | + | + | |
| 84,1 | 3 56 44,75 | 1,26 | | | | | | | |
| | | | 1,215 | 721, 0 | 719, 0 | 86160,33 | 2,418 | 5,956 | 86168,704 |
| | 48 45,75 | 1,17 | | | | | | | |
| | | | 1,115 | 721,75 | 719,75 | 86160,58 | 2,037 | 5,930 | 86168,447 |
| 84 | 20 47,50 | 1,06 | | | | | | | |
| | | | 1,015 | 723,62 | 721,62 | 86161,20 | 1,688 | 5,922 | 86168,810 |
| | 32 51,12 | 0,97 | | | | | | | |
| | | | 0, 93 | 723,13 | 721,13 | 86161,04 | 1,417 | 5,922 | 86168,379 |
| 84 | 44 54,25 | 0,89 | | | | | | | |
| | | | | | | | | | 86168,585 |
| 84,03 | Mean | | | | | | Rate of the Clock | | — 1, 46 |
| | | | | | | | | | 86167,121 |

March 30, P. M. Barometer { 30,196 / 30,117

Clock losing 1″,96 / Hygrometer 16°,2 dry. } Mean - 30,126

| Temp. | Time of coincidence. | Arc of vibration. | Mean Arc. | Interval in seconds. | Number of vibrations. | Observed vibrations in 24 hours. | Correction for Arc. | For Temperature. | Vibration in 24 hours. |
|---|---|---|---|---|---|---|---|---|---|
| | h. m. s. | ° | ° | ″ | | | + | + | |
| 84,4 | 2 57 1, 5 | 1,27 | | | | | | | |
| | | | 1,225 | 721, 0 | 719, 0 | 86160,33 | 2,459 | 6,083 | 86168,872 |
| | 3 9 2, 5 | 1,18 | | | | | | | |
| | | | 1,135 | 721,25 | 719,25 | 86160,42 | 2,111 | 6,057 | 86168,588 |
| 84,3 | 21 3,75 | 1,09 | | | | | | | |
| | | | 1,045 | 722, 5 | 720, 5 | 86160,83 | 1,789 | 6,049 | 86168,668 |
| | 33 6,25 | 1,00 | | | | | | | |
| | | | 0, 96 | 723,37 | 721,37 | 86161,12 | 1,510 | 6,049 | 86168,679 |
| 84,3 | 45 9,62 | 0,92 | | | | | | | |
| 84,33 | Mean | | | | | | Rate of the Clock | | 86168,702 — 1,960 |
| | | | | | | | | | 86166,742 |

Hygrometer 16°,5 dry. Barometer { 30,117 / 30,115

Mean - 30,116

| | h. m. s. | ° | ° | ″ | | | + | + | |
|---|---|---|---|---|---|---|---|---|---|
| 84,3 | 3 52 18,25 | 1,24 | | | | | | | |
| | | | 1, 19 | 720,62 | 718,62 | 86160,21 | 2,320 | 6,028 | 86168,558 |
| | 4 4 18,87 | 1,14 | | | | | | | |
| | | | 1,095 | 722,13 | 720,13 | 86160,71 | 1,965 | 5,985 | 86168,650 |
| 84,1 | 16 21 | 1,05 | | | | | | | |
| | | | 1,005 | 723,75 | 721,75 | 86161,24 | 1,655 | 6,008 | 86168,903 |
| | 28 24,75 | 1,96 | | | | | | | |
| | | | 0,925 | 723,63 | 721,63 | 86161,20 | 1,402 | 5,977 | 8 668,579 |
| 84 | 40 38,28 | 0,89 | | | | | | | |
| 84,13 | Mean | | | | | | Rate of the Clock | | 86168,675 — 1,960 |
| | | | | | | | | | 86166,715 |

March 30, A. M. Barometer { 30,124 / 30,144

Clock losing 2″,23 } Mean - 30,134

Hygrometer 13°,7 dry. }

| Temp. | Time of coincidence. | Arc of vibration. | Mean Arc. | Interval in seconds. | Number of vibrations. | Observed vibrations in 24 hours. | Correction for Arc. | For Temperature. | Vibrations in 24 hours. |
|---|---|---|---|---|---|---|---|---|---|
| | h. m. s. | ° | ° ′ | | | | + | + | |
| 80,1 | 6 0 30 | 1,29 | | | | | | | |
| | | | 1,245 | 720, 5 | 718, 5 | 86160,17 | 2,539 | 4,327 | 86167,036 |
| | 12 30,5 | 1,20 | | | | | | | |
| | | | 1, 16 | 721,25 | 719,25 | 86160,41 | 2,205 | 4,433 | 86167,048 |
| 80,6 | 24 31,75 | 1,12 | | | | | | | |
| | | | 1, 08 | 721,87 | 719,87 | 86160,62 | 1,911 | 4,518 | 86167,049 |
| | 36 33,62 | 1,04 | | | | | | | |
| | | | 1, 0 | 723,50 | 721,50 | 86161,16 | 1,639 | 4,577 | 86167,376 |
| 80,9 | 48 37,12 | 0,96 | | | | | | | |
| 80,53 | Mean | | | | | Rate of the Clock | | | 86167,127 — 2, 23 |
| | | | | | | | | | 86164,897 |

Hygrometer 13°,3 dry. Barometer { 30,144 / 30,162

Mean - 30,153

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | h. m. s. | ° | ° ″ | | | | + | + | |
| 81 | 6 59 7,12 | 1,19 | | | | | | | |
| | | | 1,145 | 722,75 | 720,75 | 86160,91 | 2,148 | 4,695 | 86167,753 |
| | 7 11 9,87 | 1,10 | | | | | | | |
| | | | 1, 05 | 723,63 | 721,63 | 86161,20 | 1,806 | 4,780 | 86167,786 |
| 81,4 | 23 13, 5 | 1, 0 | | | | | | | |
| | | | 0,965 | 724, 0 | 722, 0 | 86161,33 | 1,526 | 4,843 | 86167,699 |
| | 35 17, 5 | 0,93 | | | | | | | |
| | | | 0,905 | 724, 5 | 722, 5 | 86161,49 | 1,341 | 4,886 | 86167,717 |
| 81,6 | 47 22, 0 | 0,88 | | | | | | | |
| 81,33 | Mean | | | | | Rate of the Clock | | | 86167,739 — 2,230 |
| | | | | | | | | | 86165,509 |

March 31, P. M. Barometer { 30,07 / 30,066

Clock losing 2″,24
Hygrometer 16°,2 dry. } Mean - 30,068

| Temp. | Time of coincidence. | Arc of vibration. | Mean Arc. | Interval in seconds. | Number of vibrations. | Observed vibrations in 24 hours. | Correction for Arc. | For Temperature. | Vibrations in 24 hours. |
|---|---|---|---|---|---|---|---|---|---|
| | h. m. s. | ° | ° | ″ | | | + | + | |
| 85,1 | 3 8 27,5 | 1,24 | | | | | | | |
| | | | 1, 19 | 718,25 | 716,25 | 86159,42 | 2,320 | 6,366 | 86168,106 |
| | 20 25,75 | 1,14 | | | | | | | |
| | | | 1,095 | 719,37 | 717,37 | 86159,78 | 1,965 | 6,324 | 86168,069 |
| 84,9 | 32 25,12 | 1,05 | | | | | | | |
| | | | 1,005 | 720,58 | 718,38 | 86160,13 | 1,656 | 6,273 | 86168,059 |
| | 44 25, 5 | 0,96 | | | | | | | |
| | | | 0,940 | 719,75 | 717,75 | 86159,92 | 1,448 | 6,210 | 86167,578 |
| 84,6 | 56 25,25 | 0,88 | | | | | | | |
| | | | | | | | | | 86167,953 |
| 84,87 | Mean | | | | | Rate of the Clock | | | — 2,240 |
| | | | | | | | | | 86165,713 |

Hygrometer 16°,3 dry. Barometer { 30,066 / 30,061

Mean - 30,064

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | h. m. s. | ° | ° | ″ | | | + | + | |
| 84,6 | 4 6 55, 5 | 1,37 | | | | | | | |
| | | | 1,32 | 716,62 | 714,62 | 86158,87 | 2,855 | 6,155 | 86167,880 |
| | 18 52,12 | 1,27 | | | | | | | |
| | | | 1,22 | 717,75 | 715,75 | 86159,24 | 2,439 | 6,112 | 86167, 79 |
| 84,4 | 30 49,87 | 1,17 | | | | | | | |
| | | | 1,12 | 720,00 | 718,00 | 86160,00 | 2,055 | 6,074 | 86168,129 |
| | 42 49,87 | 1,07 | | | | | | | |
| | | | 1,02 | 719,75 | 717,75 | 86159,67 | 1,705 | 6,049 | 86167,424 |
| 84,26 | 54 49,62 | 0,97 | | | | | | | |
| | | | | | | | | | 86167,806 |
| 84,42 | Mean | | | | | Rate of the Clock | | | — 2,240 |
| | | | | | | | | | 86165,566 |

March 31, P. M.

Clock losing 2″10
Hygrometer 14°,6 dry.

Barometer { 30,098 / 30,114
Mean - 30,106

| Temp. | Time of coincidence. | Arc of vibration. | Mean Arc. | Interval in seconds. | Number of vibrations. | Observed vibrations in 24 hours. | Correction for Arc. | For Temperature. | Vibrations in 24 hours. |
|---|---|---|---|---|---|---|---|---|---|
| | h. m. s. | ° | ° | ″ | | | + | + | |
| 81,3 | 5 59 27, 5 | 1,21 | | | | | | | |
| | | | 1, 17 | 721, 5 | 719, 5 | 86160,50 | 2,243 | 4,763 | 86167,506 |
| | 6 11 28, 5 | 1,13 | | | | | | | |
| | | | 1,095 | 723,12 | 721,12 | 86161,03 | 1,964 | 4,733 | 86167,727 |
| 81,15 | 23 31,62 | 1,06 | | | | | | | |
| | | | 1,025 | 723,88 | 721,88 | 86161,29 | 1,721 | 4,725 | 86167,736 |
| | 35 35, 5 | 0,99 | | | | | | | |
| | | | 0,955 | 724,87 | 722,87 | 86161,61 | 1,494 | 4,750 | 86167,854 |
| | | 0,92 | | | | | | | |
| 81,23 | Mean | | | | | Rate of the Clock | | | 86167,706 |
| | | | | | | | | | — 2,100 |
| | | | | | | | | | 86165,606 |

Hygrometer 18°,5 dry.

Barometer { 30,114 / 30,130
Mean - 30,122

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | h. m. s. | ° | ° | ″ | | | + | + | |
| 81,35 | 6 59 59, 5 | 1,20 | | | | | | | |
| | | | 1, 16 | 722,75 | 720,75 | 86160,91 | 2,205 | 4,822 | 86167,937 |
| | 12 2,25 | 1,12 | | | | | | | |
| | | | 1, 08 | 724,37 | 722,37 | 86161,45 | 1,911 | 4,864 | 86168,225 |
| 81,55 | 24 5,62 | 1,04 | | | | | | | |
| | | | 0,995 | 725,75 | 723,75 | 86161,90 | 1,622 | 4,941 | 86168,463 |
| | 36 12,37 | 0,95 | | | | | | | |
| | | | 0, 91 | 726,63 | 724,63 | 86162,19 | 1,357 | 5,021 | 86168,568 |
| 81,95 | 48 19,00 | 0,87 | | | | | | | |
| 81,62 | Mean | | | | | Rate of the Clock | | | 86168,298 |
| | | | | | | | | | — 2,100 |
| | | | | | | | | | 86166,198 |

April 1, P. M. Barometer { 30,100 / 30,087

Clock losing 1″85 / Hygrometer 16°8 dry. } Mean - 30,094

| Temp. | Time of coincidence. | Arc of vibration. | Mean Arc. | Interval in seconds. | Number of vibrations. | Observed vibrations in 24 hours. | Correction for Arc. | For Temperature. | Vibrations in 24 hours. |
|---|---|---|---|---|---|---|---|---|---|
| | h. m. s. | ° | ° | ″ | | | + | + | |
| 85,3 | 2 23 30,62 | 1, 18 | | | | | | | |
| | | | 1,137 | 717,52 | 715,52 | 86159,17 | 2,118 | 6,473 | 86167,761 |
| | 35 28,12 | 1,095 | | | | | | | |
| | | | 1,048 | 720,13 | 718,13 | 86160,04 | 1,799 | 6,473 | 86168,312 |
| 85,3 | 47 28,25 | 1,000 | | | | | | | |
| | | | 0, 96 | 720,75 | 718,75 | 86160,25 | 1,510 | 6,455 | 86168,215 |
| | 59 29 | 0, 92 | | | | | | | |
| | | | 0,883 | 721, 5 | 719, 5 | 86160,50 | 1,278 | 6,425 | 86168,203 |
| 85,15 | 3 11 30, 5 | 0,845 | | | | | | | |
| 85,25 | Mean | | | | | | Rate of the Clock | | 86168,123 — 1,850 |
| | | | | | | | | | 86166,273 |

Hygrometer 16°,8 dry. Barometer { 30,087 / 30,083

Mean - 30,085

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | h. m. s. | ° | ° | ″ | | | + | + | |
| 85,15 | 3 19 39,75 | 1,27 | | | | | | | |
| | | | 1,21 | 719,25 | 717,25 | 86159,75 | 2,399 | 6,404 | 86168,553 |
| | 31 39 | 1,15 | | | | | | | |
| | | | 1,10 | 719,62 | 717,62 | 86159,87 | 1,983 | 6,396 | 86168,249 |
| 85,10 | 43 38,62 | 1,05 | | | | | | | |
| | | | 1,01 | 720,63 | 718,63 | 86160,21 | 1,671 | 6,383 | 86168,264 |
| | 55 39,25 | 0,97 | | | | | | | |
| | | | 0,93 | 722,00 | 720,00 | 86160,66 | 1,417 | 6,375 | 86168,452 |
| 85,06 | 4 7 41,25 | 0,89 | | | | | | | |
| 85,10 | Mean | | | | | | Rate of the Clock | | 86168,379 — 1,850 |
| | | | | | | | | | 86166,529 |

April 1, P. M. Barometer { 30,126 / 30,134

Clock losing 1″,86 / Hygrometer 48° dry. Mean - 30,130

| Temp. | Time of coincidence. | Arc of vibration. | Mean Arc. | Interval in seconds. | Number of vibrations. | Observed vibrations in 24 hours. | Contraction. for Arc. | For Temperature. | Vibrations in 24 hours. |
|---|---|---|---|---|---|---|---|---|---|
| | h. m. s. | ° | ° | ″ | | | + | + | |
| 81,95 | 6 16 49,75 | 1, 19 | | | | | | | |
| | | | 1,145 | 722,25 | 720,25 | 86160,83 | 2,148 | 5,114 | 86168,092 |
| | 18 52,0 | 1, 10 | | | | | | | |
| | | | 1,055 | 723,13 | 721,13 | 86161,04 | 1,824 | 5,233 | 86168,097 |
| 82,5 | 40 55,13 | 1, 01 | | | | | | | |
| | | | 0,978 | 723,37 | 721,37 | 86161,12 | 1,567 | 5,300 | 86167,987 |
| | 52 58,5 | 0,945 | | | | | | | |
| | | | 0,912 | 723,62 | 721,62 | 86161,20 | 1,363 | 5,321 | 86167,884 |
| 82,6 | 7 5 2,12 | 0, 88 | | | | | | | |
| 82,35 | Mean | | | | | Rate of the Clock | | | 86168,015 |
| | | | | | | | | | — 1,860 |
| | | | | | | | | | 86166,155 |

Hygrometer 18°,8 dry. Barometer { 30,134 / 30,172

Mean - 30,158

| | h. m. s. | ° | ° | ″ | | | + | + | |
|---|---|---|---|---|---|---|---|---|---|
| 82,6 | 7 13 12,62 | 1,195 | | | | | | | |
| | | | 1,148 | 722 | 720 | 86161,00 | 2,159 | 5,355 | 86168,514 |
| | 25 14,62 | 1, 10 | | | | | | | |
| | | | 1, 06 | 723,88 | 721,88 | 86161,28 | 1,841 | 5,410 | 86168,531 |
| 82,85 | 37 18,5 | 1, 02 | | | | | | | |
| | | | 0, 98 | 725,12 | 723,12 | 86161,69 | 1,574 | 5,444 | 86868,708 |
| | 49 23,62 | 0, 94 | | | | | | | |
| | | | 0, 89 | 725,63 | 723,63 | 86161,86 | 1,321 | 5,469 | 86168,650 |
| 82,95 | 8 1 29,25 | 0,855 | | | | | | | |
| 82,80 | Mean | | | | | Rate of the Clock | | | 86168,601 |
| | | | | | | | | | — 1,860 |
| | | | | | | | | | 86166,741 |

April 2, P. M. Barometer { 30,135 / 30,127

Clock losing 2″09 / Hygrometer 16°,7 dry. } Mean - 30,131

| Tem. | Time of coincidence. | Arc of vibration. | Mean Arc. | Interval in seconds. | Number of vibrations. | Observed vibrations in 24 hours. | Correction for Arc. | For Temperature. | Vibrations in 24 hours. |
|---|---|---|---|---|---|---|---|---|---|
| | h. m. s. | ° | ° | ″ | | | + | + | |
| 85,75 | 2 52 1,5 | 1, 23 | | | | | | | |
| | | | 1, 18 | 719,62 | 717,62 | 86159,87 | 2,281 | 6,620 | 86168,771 |
| | 3 4 1,12 | 1, 13 | | | | | | | |
| | | | 1,085 | 719,88 | 717,88 | 86159,96 | 1,929 | 6,535 | 86168,424 |
| 85,35 | 16 1,0 | 1, 04 | | | | | | | |
| | | | 0,993 | 721, 0 | 719, 0 | 86160,33 | 1,616 | 6,455 | 86168,401 |
| | 28 2 | 0,945 | | | | | | | |
| | | | 0, 91 | 720,12 | 718,12 | 86160,04 | 1,357 | 6,383 | 86167,780 |
| 85,0 | 40 2,12 | 0,875 | | | | | | | |
| 85,37 | Mean | | | | | Rate of the Clock | | | 86168,344 — 2,090 |
| | | | | | | | | | 86166,254 |

Hygrometer 16°7 dry. Barometer { 30,127 / 30,118

Mean - 30,123

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | h. m. s. | | ° | ″ | | | + | + | |
| 85 | 3 46 27,87 | 1,195 | | | | | | | |
| | | | 1,153 | 719,88 | 717,88 | 86159,96 | 2,178 | 6,324 | 86168,462 |
| | 58 27,75 | 1,110 | | | | | | | |
| | | | 1,052 | 720,25 | 718,25 | 86160,08 | 1,813 | 6,282 | 86168,175 |
| 84,8 | 4 10 28,0 | 0,995 | | | | | | | |
| | | | 0,958 | 722,12 | 720,12 | 86160,70 | 1,504 | 6,260 | 86168,464 |
| | 22 30,12 | 0, 92 | | | | | | | |
| | | | 0,885 | 722,03 | 720,03 | 86160,68 | 1,283 | 6,260 | 86168,223 |
| | 34 32,15 | 0, 85 | | | | | | | |
| 84,87 | Mean | | | | | Rate of the Clock | | | 86168,331 — 2,090 |
| | | | | | | | | | 86166,241 |

The correction for the arc of vibration was ascertained by multiplying the square of the mean arc by 1,6385. The correction for temperature was found as follows: the mean of the thermometer at the beginning and middle of the observations was taken, and that of the middle and end; which gave five heights, one for each observation; the mean of the first and second, of the second and third, and so on in succession was taken, which gave four mean heights; the difference between each of these and 70° was multiplied by 0,423, the part of a vibration due to each degree of the thermometer, as furnished by Captain KATER, and the required correction was obtained.

The rate of the clock was found as before mentioned. The following shows the daily rate of the transit clock, in the interval during which the observations were taken; and furnishes a satisfactory example of the good performance of this standard for finding the rate of the other clock.

*Rate of the Transit Clock.*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| March 22 | - | - | − 0,25 | March 29 | - | - | + 0,09 |
| 23 | - | - | + 0,13 | 30 | - | - | + 0,05 |
| 24 | - | - | − 0,05 | 31 | - | - | − 0,03 |
| 25 | - | - | + 0,23 | April 1 | - | - | + 0,02 |
| 26 | - | - | + 0,10 | 2 | - | - | − 0,08 |
| 27 | - | - | + 0,15 | 3 | - | - | + 0,05 |
| 28 | - | - | + 0,20 | 4 | - | - | − 0,04 |

*Table of the Results of the foregoing Experiments.*

| Day, 1821. | Time of the Experiment. | Mean Height of the Thermometer. | Mean Height of the Barometer. | Mean Height of the Hygrometer. | Number of Vibrations in 24 hours, at the temperature of 70° of Farnheit. |
|---|---|---|---|---|---|
| | | ° | Inch. | dry. | |
| March 24 | A. M. | 81,25 | 30,093 | | 86166,908 |
| | | 81,73 | 30,114 | | 86167,339 |
| | | 83,53 | 30,135 | | 86166,273 |
| | | 84,83 | 30,135 | 12,25 | 86167,047 |
| | | 84,97 | 30,141 | | 86166,218 |
| 25 | A. M. | 80,83 | 30,145 | | 86165,111 |
| | | 81, 6 | 30,154 | 12,22 | 86166,083 |
| 26 | P. M. | 83, 8 | 30,133 | | 86165,176 |
| | A. M. | 79,53 | 30,149 | 14, 4 | 86165,377 |
| | | 80,67 | 30,102 | | 86165,971 |
| 27 | P. M. | 84,37 | 30,123 | | 86164,930 |
| | | 83,83 | 30,109 | 19, 6 | 86165,320 |
| 29 | P. M. | 84, 3 | 30,098 | | 86167,004 |
| | | 84,03 | 30,100 | 17, 7 | 86167,121 |
| 30 | P. M. | 84,33 | 30,126 | | 86166,742 |
| | | 84,13 | 30,116 | | 86166,715 |
| | A. M. | 80,53 | 30,134 | 14,92 | 86164,897 |
| | | 81,33 | 30,153 | | 86165,509 |
| 31 | P. M. | 84,87 | 30,068 | | 86165,713 |
| | | 84,42 | 30,064 | 15,15 | 86165,566 |
| | A. M. | 81,23 | 30,106 | | 86165,606 |
| | | 81,62 | 30,122 | | 86166,198 |
| April 1 | P. M. | 85,25 | 30,094 | | 86166,273 |
| | | 85,10 | 30,085 | | 86166,529 |
| | A. M. | 82,35 | 30,130 | 15,65 | 86166,155 |
| | | 82,80 | 30,153 | | 86166,741 |
| 2 | P. M. | 85,37 | 30,131 | | 86166,254 |
| | | 84,87 | 30,123 | 16, 7 | 86166,241 |
| Mean | | 83,48 | 30,121 | 15,38 | 86166,108 |

*Second Series of Experiments for ascertaining the length of the Pendulum at Madras.*

Thinking it possible that these Observations might be referred to by future observers in other parts of the world, and wishing to have as accurate results as I could obtain, I deter-

mined to take a second series; having made what I considered some improvement in detaching the clock and apparatus from the floor of the building. In this series, besides comparisons for the rate of the clock used in the experiments, with the transit clock at the time of making the experiments, transits of stars were taken with this clock for the purpose. The result of this series, however, seems to prove, that every necessary precaution had been used in the first, the difference of the two being only 0,06 of a vibration in 24 hours.*

The following are the Observations of the Second Series.

## OBSERVATIONS.

### SECOND SERIES.

April 18th A. M. Barometer { 30,018 / 30,029

Rate of Clock + 0″,97 } Mean - 30,025
Hygrometer 12°,6 dry. }

| Temp. | Time of coincidence. | Arc of vibration. | Mean Arc. | Interval in seconds. | Number of vibrations. | Observed vibrations in 24 hours. | Correction for Arc. | For temperature. | Vibrations in 24 hours. |
|---|---|---|---|---|---|---|---|---|---|
| | h. m. s. | ° | ° | ″ | | | + | + | |
| 82,7 | 18 14 21,75 | 1,275 | | | | | | | |
| | | | 1,122 | 711,12 | 709,12 | 86157,00 | 2,447 | 5,402 | 86164,849 |
| | 26 12,87 | 1, 17 | | | | | | | |
| | | | 1,125 | 712,63 | 710,63 | 86157,52 | 2,074 | 5,469 | 86165,063 |
| 83 | 38 5,50 | 1, 08 | | | | | | | |
| | | | 1,035 | 713, 0 | 711, 0 | 86157,64 | 1,755 | 5,550 | 86164,945 |
| | 49 58,50 | 0, 99 | | | | | | | |
| | | | 0,953 | 713,62 | 711,62 | 86157,86 | 1,488 | 5,643 | 86164,691 |
| 83,45 | 19 1 52,12 | 0,915 | | | | | | | |
| | | | | | | | | | 86164,887 |
| 83,05 | Mean | | | | | | Rate of the Clock | | + 0,970 |
| | | | | | | | | | 86165,857 |

* By rejecting the 4 in each series, which differs most from the mean, we obtain a mean 0,03 of a vibration less than that from which the conclusions have been drawn.

Barometer { 30,029 / 30,044

Mean - 30,037

| Temp. | Time of coincidence. | Arc of vibration. | Mean Arc. | Interval in seconds. | Number of vibrations. | Observed vibrations in 24 hours. | Correction for Arc. | For Temperature. | Vibrations in 24 hours. |
|---|---|---|---|---|---|---|---|---|---|
| | h. m. s. | ° | ° | " | | | + | + | |
| 83,45 | 19 11 27,12 | 1, 30 | | | | | | | |
| | | | 1, 25 | 708,63 | 706,63 | 86156,15 | 2,560 | 5,748 | 86164,478 |
| | 23 15,75 | 1, 20 | | | | | | | |
| | | | 1,155 | 711,38 | 709,38 | 86157,09 | 2,186 | 5,863 | 86165,539 |
| 84,0 | 35 7,13 | 1, 11 | | | | | | | |
| | | | 1,067 | 711,12 | 709,12 | 86157,00 | 1,865 | 5,985 | 86164,850 |
| | 46 58,25 | 1,025 | | | | | | | |
| | | | 0,990 | 712,12 | 710,12 | 86157,34 | 1,606 | 6,112 | 86165,058 |
| | | | | | | | | | |
| 84,02 | Mean | | | | | | Rate of the Clock | | 86164,981 + ,970 |
| | | | | | | | | | 86165,951 |

Hygrometer 15° dry.

Barometer { 30,044 / 30,045

Mean - 30,044

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | h. m. s. | ° | ° | " | | | + | + | |
| 84,6 | 20 13 1, 5 | 1, 39 | | | | | | | |
| | | | 1,337 | 709, 0 | 707, 0 | 86156,28 | 2,929 | 6,218 | 86165,424 |
| | 24 50, 5 | 1,285 | | | | | | | |
| | | | 1,233 | 708,75 | 706,75 | 86156,19 | 2,491 | 6,303 | 86164,984 |
| 85 | 36 39,25 | 1, 18 | | | | | | | |
| | | | 1,132 | 710, 0 | 708 | 86156,66 | 2,100 | 6,396 | 86165,156 |
| | 48 29,25 | 1,085 | | | | | | | |
| | | | 1,043 | 709,37 | 707,37 | 86156,40 | 1,782 | 6,502 | 86164,684 |
| | | | | | | | | | |
| 85,04 | Mean | | | | | | Rate of the Clock | | 86165,062 + ,970 |
| | | | | | | | | | 86166,032 |

April 19, P. M. Barometer $\begin{cases} 29.983 \\ 29.961 \end{cases}$

Rate of Clock 0″88 } Hygrometer 16°5 dry. } Mean - 29.972

| Temp. | Time of coincidence. | Arc of vibration. | Mean Arc. | Interval in seconds. | Number of vibrations. | Observed vibrations in 24 hours. | Correction for Arc. | For Temperature. | Vibrations in 24 hours. |
|---|---|---|---|---|---|---|---|---|---|
| | h. m. s. | ° | ° | ″ | | | + | + | |
| 87,5 | 2 21 17,62 | 1,275 | | | | | | | |
| | | | 1.223 | 707,50 | 705,50 | 86155,76 | 2,451 | 7,386 | 86165,597 |
| | 33 5,12 | 1,170 | | | | | | | |
| | | | 1,112 | 708,50 | 706,50 | 86156,21 | 2,026 | 7,356 | 86165,392 |
| 87,35 | 44 53,62 | 1,055 | | | | | | | |
| | | | 1,015 | 710,88 | 708,88 | 86157,06 | 1,688 | 7,318 | 86166,066 |
| | 56 44, 5 | 0,975 | | | | | | | |
| | | | 0,933 | 709,62 | 707,62 | 86156,49 | 1,426 | 7,276 | 86165,192 |
| 87,15 | 3 8 34,12 | 0,890 | | | | | | | |
| 87,33 | Mean | | | | | Rate of the Clock | | | 86165,562 + ,880 |
| | | | | | | | | | 86166,442 |

Barometer $\begin{cases} 29,961 \\ 29.952 \end{cases}$

Mean - 29,956

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | h. m. s. | ° | ° | ″ | | | + | + | |
| 87,1 | 3 17 0,12 | 1, 26 | | | | | | | |
| | | | 1, 20 | 708,50 | 706,50 | 86156,01 | 2,359 | 7,212 | 86165,461 |
| | 28 48,62 | 1, 14 | | | | | | | |
| | | | 1,093 | 707,88 | 705,88 | 86155,89 | 1,958 | 7,170 | 86165,018 |
| 86,9 | 40 36, 5 | 1,045 | | | | | | | |
| | | | 1,013 | 710,62 | 708,62 | 86156,83 | 1,681 | 7,136 | 86165,647 |
| | 52 27,12 | 0, 98 | | | | | | | |
| | | | 0,935 | 710,50 | 708,50 | 86156,79 | 1,432 | 7,115 | 86165,337 |
| 86,8 | 4 4 17,62 | 0, 89 | | | | | | | |
| 86,93 | Mean | | | | | Rate of the Clock | | | 86165,366 + ,880 |
| | | | | | | | | | 86166,246 |

Hygrometer 16°5 dry. Barometer { 29.952 / 29.948 } Mean = 29,950

| Temp. | Time of coincidence. | Arc of vibration. | Mean Arc. | Interval in seconds. | Number of vibrations. | Observed vibrations in 24 hours. | Correction for Arc. | For Temperature. | Vibrations in 24 hours. |
|---|---|---|---|---|---|---|---|---|---|
| | h. m. s. | ° | ° | " | | | + | + | |
| 86,8 | 4 13 57,4 | 1,19 | | | | | | | |
| | | | 1, 14 | 709,22 | 707,22 | 86156,35 | 2,129 | 7,064 | 86165,543 |
| | 23 46,62 | 1,09 | | | | | | | |
| | | | 1,045 | 710, 0 | 708, 0 | 86156,62 | 1,789 | 6,679 | 86165,388 |
| 86,4 | 35 36,62 | 1,00 | | | | | | | |
| | | | 0,955 | 711,75 | 709,75 | 86157,22 | 1,491 | 6,908 | 86165,619 |
| | 47 28,37 | 0,91 | | | | | | | |
| | | | 0,865 | 712,25 | 710,25 | 86157,39 | 1,226 | 6,840 | 86165,456 |
| 86,1 | 59 20,62 | 0,82 | | | | | | | |
| 86,43 | Mean | | | | | | Rate of the Clock | | 86165,502 + ,880 |
| | | | | | | | | | 86166,382 |

April 19, A. M. 18h 20 Civil. Barometer { 30,046 / 30,041 }

Rate of Clock + 0"70 Hygrometer 18°4 dry. Mean - 30,044

| | h. m. s. | ° | ° | " | | | + | + | |
|---|---|---|---|---|---|---|---|---|---|
| 83 | 17 54 47,62 | 1, 29 | | | | | | | |
| | | | 1,243 | 710,25 | 708,25 | 86156,705 | 2,532 | 5,562 | 86164,799 |
| | 18 6 37,87 | 1,195 | | | | | | | |
| | | | 1,150 | 711,50 | 709, 5 | 86157,132 | 2,167 | 5,689 | 86164,988 |
| 83,6 | 18 29,37 | 1,105 | | | | | | | |
| | | | 1,067 | 712,50 | 709,50 | 86157,132 | 1,865 | 5,753 | 86164,750 |
| | 30 20,87 | 1,030 | | | | | | | |
| | | | 0,995 | 713,63 | 711,63 | 86157,843 | 1,622 | 5,753 | 86165,218 |
| 83,6 | 42 14, 5 | 0, 96 | | | | | | | |
| 83,4 | Mean | | | | | | Rate of the Clock | | 86164,939 +0,700 |
| | | | | | | | | | 86165,639 |

Barometer { 30,041 / 30,050

Mean - 30,045

| Temp. | Time of coincidence. | Arc of vibration. | Mean Arc. | Interval in seconds. | Number of vibrations. | Observed vibrations in 24 hours. | Correction for Arc. | For Temperature. | Vibrations in 24 hours. |
|---|---|---|---|---|---|---|---|---|---|
| | h. m. s. | ° | ° | ″ | | | + | + | |
| 83,6 | 18 49 21 | 1,305 | | | | | | | |
| | | | 1,257 | 709,75 | 707,75 | 86156,533 | 2,589 | 5,795 | 86164,917 |
| | 19 1 10,75 | 1, 21 | | | | | | | |
| | | | 1, 16 | 712,37 | 710,37 | 86157,429 | 2,205 | 5,880 | 86165,514 |
| 84 | 13 3,12 | 1, 11 | | | | | | | |
| | | | 1, 07 | 711,38 | 709,38 | 86157,091 | 1,876 | 5,951 | 86164,918 |
| | 24 54, 5 | 1, 03 | | | | | | | |
| | | | 1, 00 | 713, 5 | 711, 5 | 86157,813 | 1,638 | 6,002 | 86165,453 |
| 84,25 | 36 48 | 0, 97 | | | | | | | |
| 83,95 | Mean | | | | | | Rate of the Clock | | 86165,200 + ,700 |
| | | | | | | | | | 86165,900 |

Hygrometer 18°,6.

Barometer { 30,050 / 30,036

Mean - 30,043

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | h. m. s. | ° | ° | ″ | | | + | + | |
| 84,25 | 19 44 11, 5 | 1, 25 | | | | | | | |
| | | | 1, 21 | 710,25 | 708,25 | 86156,705 | 2,399 | 6,104 | 86165,208 |
| | 56 1,75 | 1, 17 | | | | | | | |
| | | | 1,125 | 711,37 | 709,37 | 86157,088 | 2,074 | 6,252 | 86165,414 |
| 84,95 | 20 7 53,12 | 1, 08 | | | | | | | |
| | | | 1,038 | 711,50 | 709,50 | 86157,132 | 1,765 | 6,341 | 86165,238 |
| | 19 44,62 | 0,995 | | | | | | | |
| | | | 0,958 | 712,13 | 710,13 | 86157,347 | 1,504 | 6,370 | 86165,221 |
| 85,1 | 31 36,75 | 0,920 | | | | | | | |
| 84,77 | Mean | | | | | | Rate of the Clock | | 86165,270 + ,700 |
| | | | | | | | | | 86165,700 |

April 20, P. M. Barometer { 30,008 / 29,982

Rate of Clock + 0″,46
Hygrometer 16° 7 dry. } Mean - 29,995

| Temp. | Time of coincidence. | Arc of vibration. | Mean Arc. | Interval in seconds. | Number of vibrations. | Observed vibrations in 24 hours. | Correction for Arc. | For Temperature. | Vibrations in 24 hours. |
|---|---|---|---|---|---|---|---|---|---|
| | h. m. s. | ° | ° | ″ | | | + | + | |
| 87,5 | 2 11 25, 5 | 1,195 | | | | | | | |
| | | | 1,148 | 707, 0 | 705, 0 | 86155,586 | 2,159 | 7,360 | 86165,105 |
| | 23 12, 5 | 1, 10 | | | | | | | |
| | | | 1,055 | 708 | 706 | 86155,932 | 1,824 | 7,276 | 86165,032 |
| 87,1 | 35 0, 5 | 1, 01 | | | | | | | |
| | | | 0,975 | 709,25 | 707,25 | 86156,362 | 1,557 | 7,233 | 86165,152 |
| | 46 49,75 | 0, 94 | | | | | | | |
| | | | 0,905 | 708,75 | 706,75 | 86156,190 | 1,342 | 7,233 | 86164,765 |
| 87,1 | 58 58, 5 | 0, 87 | | | | | | | |
| 87,23 | Mean | | | | | Rate of the Clock | | | 86165,013 + ,460 |
| | | | | | | | | | 86165,473 |

Barometer { 29,982 / 29,977

Mean - 29,979

| | h. m. s. | ° | ° | ″ | | | + | + | |
|---|---|---|---|---|---|---|---|---|---|
| 87,0 | 3 5 32,62 | 1,205 | | | | | | | |
| | | | 1,158 | 707, 0 | 705 | 86155,586 | 2,197 | 7,191 | 86164,974 |
| | 17 19,62 | 1, 11 | | | | | | | |
| | | | 1,065 | 708,63 | 706,63 | 86156,149 | 1,858 | 7,191 | 86165,198 |
| 87,0 | 29 8,25 | 1, 02 | | | | | | | |
| | | | 0,985 | 708,75 | 706,75 | 86156,190 | 1,590 | 7,191 | 86164,971 |
| | 40 57, 0 | 0, 95 | | | | | | | |
| | | | 0, 92 | 710,62 | 708,62 | 86156,832 | 1,387 | 7,191 | 86165,410 |
| 87 | 52 47,62 | 0, 89 | | | | | | | |
| 87,0 | Mean | | | | | Rate of the Clock | | | 86165,138 + ,460 |
| | | | | | | | | | 86165,598 |

Hygrometer 17°,5 dry. Barometer { 30,030 / 30,032

Mean - 30,031

| Temp. | Time of coincidence. | Arc of vibration. | Mean Arc. | Interval in seconds. | Number of vibrations. | Observed vibrations in 24 hours. | Correction for Arc. | For Temperature. | Vibrations in 24 hours. |
|---|---|---|---|---|---|---|---|---|---|
| | h. m. s. | ° | ° | " | | | + | + | |
| 86, 9 | 4 2 37,87 | 1,19 | | | | | | | |
| | | | 1,145 | 709,75 | 707,75 | 86156,533 | 2,148 | 7,140 | 86165,821 |
| | 14 27,62 | 1,10 | | | | | | | |
| | | | 1, 05 | 710,88 | 708,88 | 86157,061 | 1,806 | 7,115 | 86165,982 |
| 86, 8 | 26 18, 5 | 1, 0 | | | | | | | |
| | | | 0,955 | 711,37 | 709,37 | 86157,088 | 1,491 | 7,085 | 86165,664 |
| | 38 9,87 | 0,91 | | | | | | | |
| | | | 0,875 | 712,50 | 710,50 | 86157,473 | 1,255 | 7,043 | 86165,771 |
| 86, 6 | 50 2,37 | 0,84 | | | | | | | |
| | | | | | | | | | 86165,809 |
| 86,73 | Mean | | | | | | Rate of the Clock | | + ,370 |
| | | | | | | | | | 86166,179 |

April 21, A. M.

Rate of Clock 0",63
Hygrometer 14° dry.

Barometer { 30,064 / 30,062

Mean - 30,063

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | h. m. s. | ° | ° | " | | | + | + | |
| 83,4 | 17 51 37 | 1,305 | | | | | | | |
| | | | 1,255 | 708,62 | 706,62 | 86156,489 | 2,581 | 5,681 | 86164,751 |
| | 18 3 25,62 | 1,205 | | | | | | | |
| | | | 1,159 | 710,13 | 708,13 | 86156,664 | 2,201 | 5,702 | 86164,567 |
| 83,5 | 15 15,75 | 1,114 | | | | | | | |
| | | | 1,082 | 711,00 | 709,00 | 86156,692 | 1,918 | 5,732 | 86164,342 |
| | 27 6,75 | 1,060 | | | | | | | |
| | | | 1,023 | 712,12 | 710,12 | 86157,344 | 1,715 | 5,773 | 86164,832 |
| 83,7 | 38 58,87 | 0,985 | | | | | | | |
| | | | | | | | | | 86164,623 |
| 83,53 | Mean | | | | | | Rate of the Clock | | + ,630 |
| | | | | | | | | | 86165,253 |

Barometer { 30,062 / 30,068

Mean - 30,065

| Temp. | Time of coincidence. | Arc of vibration. | Mean Arc. | Interval in seconds. | Number of vibrations. | Observed vibrations in 24 hours. | Correction for Arc. | For Temperature. | Vibrations in 24 hours. |
|---|---|---|---|---|---|---|---|---|---|
| | h. m. s. | ° | ° | " | | | + | + | |
| 83,7 | 18 45 38, 5 | 1,205 | | | | | | | |
| | | | 1,157 | 709,87 | 707,87 | 86156,575 | 2,193 | 5,808 | 86164,576 |
| | 57 28,37 | 1,110 | | | | | | | |
| | | | 1,083 | 711,26 | 709,26 | 86157,050 | 1,922 | 5,829 | 86164,801 |
| 83,8 | 19 9 19,63 | 1,055 | | | | | | | |
| | | | 1,022 | 711,74 | 709,74 | 86157,214 | 1,711 | 5,858 | 86164,783 |
| | 21 11,37 | 0,990 | | | | | | | |
| | | | 0,953 | 712,50 | 710,50 | 86157,473 | 1,488 | 5,901 | 86164,862 |
| 84 | 33 3,87 | 0,915 | | | | | | | |
| 83,83 | Mean | | | | | | Rate of the Clock | | 86164,755 + ,630 |
| | | | | | | | | | 86165,385 |

Hygrometer 14° dry.

Barometer { 30,068 / 30,072

Mean - 30,070

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | h. m. s. | ° | ° | " | | | + | + | |
| 84,1 | 19 40 10 | 1, 19 | | | | | | | |
| | | | 1, 15 | 709,63 | 707,63 | 86156,492 | 2,167 | 5,985 | 86164,644 |
| | 51 59,63 | 1, 11 | | | | | | | |
| | | | 1,065 | 713,12 | 711,12 | 86157,684 | 1,858 | 6,028 | 86165,570 |
| 84,3 | 20 3 52,75 | 1, 02 | | | | | | | |
| | | | 0, 98 | 712, 0 | 710, 0 | 86157,303 | 1,574 | 6,104 | 86164,981 |
| | 15 44,75 | 0, 94 | | | | | | | |
| | | | 0,905 | 713,88 | 711,88 | 86157,942 | 1,342 | 6,209 | 86165,493 |
| 84,8 | 27 38,63 | 0, 87 | | | | | | | |
| 84,4 | Mean | | | | | | Rate of the Clock | | 86165,175 + ,630 |
| | | | | | | | | | 86165,805 |

April 22, P. M. Barometer { 30,038 / 30,025

Rate of Clock + 0″,76 }
Hygrometer 18°,4 dry. } Mean - 30,032

| Temp. | Time of coincidence. | Arc of vibration. | Mean Arc. | Interval in seconds. | Number of vibrations. | Observed vibrations in 24 hours. | Correction for Arc. | For Temperature. | Vibrations in 24 hours. |
|---|---|---|---|---|---|---|---|---|---|
| | h. m. s. | ° | ° | ″ | | | + | + | |
| 87,6 | 2 9 20,37 | 1,24 | 1,185 | 708,13 | 706,13 | 86155,977 | 2,301 | 7,411 | 86165,689 |
| | 21 8,50 | 1,13 | 1,085 | 708,37 | 706,37 | 86156,059 | 1,929 | 7,352 | 86165,340 |
| 87,3 | 32 56,87 | 1,04 | 1, 00 | 709,63 | 707,63 | 86156,492 | 1,638 | 7,309 | 86165,439 |
| | 44 46,50 | 0,96 | 0,975 | 710,87 | 708,87 | 86156,917 | 1,558 | 7,288 | 86165,763 |
| 87,2 | 56 37,37 | 0,89 | | | | | | | |
| 87,37 | Mean | | | | | | Rate of the Clock | | 86165,558 + ,760 |
| | | | | | | | | | 86166,318 |

Barometer { 30,025 / 30,017

Mean - 30,021

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | h. m. s. | ° | ° | ″ | | | + | + | |
| 87,2 | 3 3 6,37 | 1,23 | 1, 17 | 708,25 | 706,25 | 86156,018 | 2,243 | 7,268 | 86165,529 |
| | 14 54,62 | 1,11 | 1,065 | 709,01 | 707,01 | 86156,279 | 1,858 | 7,246 | 86165,383 |
| 87,1 | 26 43,63 | 1,02 | 0, 98 | 710,75 | 708,75 | 86156,876 | 1,574 | 7,221 | 86165,671 |
| | 38 34,38 | 0,94 | 0,895 | 711,49 | 709,49 | 86157,122 | 1,312 | 7,204 | 86165,638 |
| 87 | 50 25,87 | 0,85 | | | | | | | |
| 87,1 | Mean | | | | | | Rate of the Clock | | 86165,555 + ,760 |
| | | | | | | | | | 86166,315 |

Hygrometer 16°,2 dry. Barometer { 29,977 / 29,977 }

Mean - 29,977

| Temp. | Time of coincidence. | Arc of vibration. | Mean Arc. | Interval in seconds. | Number of vibrations. | Observed vibrations in 24 hours. | Correction for Arc. | For Temperature. | Vibrations in 24 hours. |
|---|---|---|---|---|---|---|---|---|---|
| | h. m. s. | ° | ° | " | | | + | + | |
| 87 | 4 0 4, 5 | 1, 30 | | | | | | | |
| | | | 1, 25 | 707,87 | 705,87 | 86155,887 | 2,560 | 7,161 | 86165,608 |
| | 11 51,37 | 1, 20 | | | | | | | |
| | | | 1,155 | 708 | 706 | 86155,932 | 2,186 | 7,094 | 86165,212 |
| 86,7 | 23 39,37 | 1, 11 | | | | | | | |
| | | | 1,067 | 709,13 | 707,13 | 86156,321 | 1,865 | 7,043 | 86165,229 |
| | 35 28, 5 | 1,025 | | | | | | | |
| | | | 0,993 | 709,87 | 707,87 | 86156,575 | 1,516 | 7, 0 | 86165,091 |
| 86,5 | 47 18,37 | 0, 96 | | | | | | | |
| 86,73 | Mean | | | | | Rate of the Clock | | | 86165,285 + ,460 |
| | | | | | | | | | 86165,745 |

April 20, A. M. Barometer { 30,047 / 30,071 }

Rate of Clock 0",22 + / Hygrometer 13°,4 } Mean - 30,059

| | h. m. s. | ° | ° | " | | | + | + | |
|---|---|---|---|---|---|---|---|---|---|
| 83,3 | 17 5 11, 5 | 1,275 | | | | | | | |
| | | | 1,233 | 711,37 | 709,37 | 86157,088 | 2,491 | 5,647 | 86165,226 |
| | 18 5 2,87 | 1, 19 | | | | | | | |
| | | | 1, 15 | 710,75 | 708,75 | 86156,876 | 2,167 | 5,689 | 86164,732 |
| 83,5 | 16 53,62 | 1, 11 | | | | | | | |
| | | | 1,065 | 712,13 | 710,13 | 86157,347 | 1,858 | 5,732 | 86164,937 |
| | 28 45,75 | 1,020 | | | | | | | |
| | | | 0,990 | 711,00 | 709,00 | 86156,962 | 1,606 | 5,774 | 86164,342 |
| 83,7 | 40 36,75 | 0, 96 | | | | | | | |
| 83,5 | Mean | | | | | Rate of the Clock | | | 86164,809 + 0,220 |
| | | | | | | | | | 86165,029 |

Barometer { 30,071
30,088

Mean - 30,079

| Temp. | Time of coincidence. | Arc of vibration. | Mean Arc. | Interval in seconds. | Number of vibrations. | Observed vibrations in 24 hours. | Correction for Arc. | For Temperature. | Vibrations in 24 hours. |
|---|---|---|---|---|---|---|---|---|---|
| | h. m. s. | ° | ° | " | | | + | + | |
| 83,7 | 18 47 47,75 | 1, 36 | | | | | | | |
| | | | 1, 31 | 709,37 | 707,37 | 86156,463 | 2,812 | 5,829 | 86165,044 |
| | 59 37,12 | 1, 26 | | | | | | | |
| | | | 1,215 | 710,51 | 708,51 | 86156,794 | 2,418 | 5,888 | 86165,100 |
| 84 | 19 11 27,63 | 1, 17 | | | | | | | |
| | | | 1, 13 | 711,87 | 709,87 | 86157,259 | 2,092 | 5,956 | 86164,842 |
| | 23 19, 5 | 1, 09 | | | | | | | |
| | | | 1,043 | 713,25 | 711,25 | 86157,728 | 1,782 | 6,015 | 86165,525 |
| 84,3 | 35 12,75 | 0,995 | | | | | | | |
| 84,0 | Mean | | | | | | Rate of the Clock | | 86165,128 + ,022 |
| | | | | | | | | | 86165,150 |

Hygrometer 13°,4 dry. Barometer { 30,088
30,082

Mean - 30,085

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | h. m. s. | ° | ° | " | | | + | + | |
| 84,35 | 19 42 26 | 1, 39 | | | | | | | |
| | | | 1,337 | 710, 0 | 708 | 86156,619 | 2,929 | 6,112 | 86165,660 |
| | 54 16 | 1,285 | | | | | | | |
| | | | 1,233 | 710, 5 | 708, 5 | 86156,790 | 2,491 | 6,197 | 86165,478 |
| 84,75 | 20 6 65 | 1,180 | | | | | | | |
| | | | 1,135 | 711,13 | 709,13 | 86157,006 | 2,111 | 6,281 | 86165,398 |
| | 17 57,63 | 1,090 | | | | | | | |
| | | | 1,045 | 713,24 | 711,24 | 86157,725 | 1,789 | 6,366 | 86165,880 |
| 85,15 | 29 50,87 | 1, 00 | | | | | | | |
| 84,75 | Mean | | | | | | Rate of the Clock | | 86165,604 + ,022 |
| | | | | | | | | | 86165,626 |

April 21, P. M. Barometer { 30,045 / 30,038

Rate of Clock + 0″,87
Hygrometer 17°,8 dry. } Mean - 30,042

| Temp. | Time of coincidence. | Arc of vibration. | Mean Arc. | Interval in seconds. | Number of vibrations. | Observed vibrations in 24 hours. | Correction for Arc. | For Temperature. | Vibrations in 24 hours. |
|---|---|---|---|---|---|---|---|---|---|
| | h. m. s. | ° | ° | ″ | | | + | + | |
| 87,5 | 2 7 33, 5 | 1,275 | | | | | | | |
| | | | 1,220 | 708, 5 | 706, 5 | 86156,104 | 2,439 | 7,373 | 86165,916 |
| | 19 22 | 1,165 | | | | | | | |
| | | | 1,123 | 709,37 | 707,37 | 86156,403 | 2,066 | 7,305 | 86165,774 |
| 87,2 | 31 11,37 | 1,080 | | | | | | | |
| | | | 1,038 | 710,25 | 708,25 | 86156,705 | 1,765 | 7,254 | 86165,724 |
| | 43 1,62 | 0,995 | | | | | | | |
| | | | 0,953 | 711,01 | 709,01 | 86156,965 | 1,488 | 7,212 | 86165,665 |
| 87 | 54 52,63 | 0,910 | | | | | | | |
| 87,23 | Mean | | | | | | Rate of the Clock | | 86165,770 |
| | | | | | | | | | + 0,370 |
| | | | | | | | | | 86166,140 |

Barometer { 30,038 / 30,030

Mean - 30,034

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 87 | h. m. s. 3 1 43,13 | ° 1, 29 | ° | ″ | | | + | + | |
| | | | 1, 23 | 708,49 | 706,49 | 86155,959 | 2,479 | 7,191 | 86165,629 |
| | 13 31,62 | 1, 17 | | | | | | | |
| | | | 1,127 | 709,88 | 707,88 | 86156,584 | 2,081 | 7,191 | 86165,856 |
| 87 | 25 21,50 | 1,085 | | | | | | | |
| | | | 1,043 | 711, 0 | 709, 0 | 86156,962 | 1,782 | 7,183 | 86165,927 |
| | 37 12, 5 | 1, 00 | | | | | | | |
| | | | 0,955 | 710,88 | 708,88 | 86157,061 | 1,491 | 7,161 | 86165,713 |
| 86,9 | 49 3,38 | 0, 91 | | | | | | | |
| 86,93 | | | | | | | Rate of the Clock | | 86165,781 |
| | | | | | | | | | + ,370 |
| | | | | | | | | | 86166,151 |

Hygrometer 17°, 5. Barometer { 30,017 / 30,007 }

Mean - 30,012

| Temp. | Time of coincidence. | Arc of vibration. | Mean Arc. | Interval in seconds. | Number of vibrations. | Observed vibrations in 24 hours. | Correction for Arc. | For Temperature. | Vibrations in 24 hours. |
|---|---|---|---|---|---|---|---|---|---|
| | h. m. s. | ° | ° | " | | | + | + | |
| 87 | 3 56 31,37 | 1,14 | | | | | | | |
| | | | 1,085 | 709,88 | 707,88 | 86156,584 | 1,929 | 7,170 | 86165,683 |
| | 4 8 21,25 | 1,03 | | | | | | | |
| | | | 0, 99 | 711,37 | 709,37 | 86157,088 | 1,606 | 7,127 | 86165,821 |
| 86,8 | 20 12,62 | 0,95 | | | | | | | |
| | | | 0, 91 | 711,51 | 709,51 | 86157,136 | 1,357 | 7,106 | 86165,599 |
| | 32 4,13 | 0,87 | | | | | | | |
| | | | 0, 83 | 712,75 | 710,75 | 86157,558 | 1,128 | 7,106 | 86165,792 |
| 86,8 | 43 56,88 | 0,79 | | | | | | | |
| | | | | | | | | | 86165,724 |
| 86,87 | Mean | | | | | Rate of the Clock | | | + ,760 |
| | | | | | | | | | 86166,484 |

April 22, A. M. Barometer { 30,022 / 30,016 }

Rate of Clock + 0″98

Hygrometer 15° dry (beginning.) Mean - 30,019

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | h. m. s. | ° | ° | " | | | + | + | |
| 83,2 | 17 45 46 | 1,26 | | | | | | | |
| | | | 1, 22 | 714 | 712 | 86157,983 | 2,439 | 5,596 | 86166,018 |
| | 57 40 | 1,18 | | | | | | | |
| | | | 1,135 | 715,62 | 713,62 | 86158,531 | 2,110 | 5,617 | 86166,258 |
| 83,3 | 18 9 35,62 | 1,09 | | | | | | | |
| | | | 1,045 | 716,88 | 714,88 | 86158,955 | 1,789 | 5,626 | 86166,370 |
| | 21 32, 5 | 1, 0 | | | | | | | |
| | | | 0,965 | 718, 5 | 716, 5 | 86159,498 | 1,526 | 5,626 | 86166,650 |
| 83,3 | 33 31 | 0,93 | | | | | | | |
| | | | | | | | | | 86166,324 |
| 83,27 | Mean | | | | | Rate of the Clock | | | + ,980 |
| | | | | | | | | | 86167,304 |

Hygrometer 14°,2 dry (end.) Barometer { 30,016 / 30,040

Mean - 30,028

| Temp. | Time of coincidence. | Arc of vibration. | Mean Arc. | Interval in seconds. | Number of vibrations. | Observed vibrations in 24 hours. | Correction for Arc. | For Temperature. | Vibrations in 24 hours. |
|---|---|---|---|---|---|---|---|---|---|
| | h. m. s. | ° | ° | ″ | | | + | + | |
| 83,4 | 18 43 3,87 | 1, 21 | | | | | | | |
| | | | 1, 16 | 715,63 | 713,63 | 86158,534 | 2,203 | 5,702 | 86166,441 |
| | 54 59, 5 | 1,111 | | | | | | | |
| | | | 1,076 | 717,25 | 715,25 | 86159,079 | 1,897 | 5,765 | 86166,741 |
| 83,7 | 19 6 56,75 | 1, 04 | | | | | | | |
| | | | 1, 00 | 717,75 | 715,75 | 86159,247 | 1,638 | 5,829 | 86166,714 |
| | 18 54, 5 | 0, 96 | | | | | | | |
| | | | 0, 92 | 718,50 | 716,50 | 86159,498 | 1,387 | 5,888 | 86166,773 |
| 84 | 30 53, 0 | 0, 88 | | | | | | | |
| 83,7 | Mean | | | | | | Rate of the Clock | | 86166,667 |
| | | | | | | | | | + ,980 |
| | | | | | | | | | 86167,647 |

April 23, P. M. Barometer { 30,017 / 30,008

Rate of Clock + 0″,99 } Mean - 30,012

Hygrometer 18°,8 dry. }

| | h. m. s. | ° | ° | ″ | | | + | + | |
|---|---|---|---|---|---|---|---|---|---|
| 87,6 | 2 26 10,12 | 1,25 | | | | | | | |
| | | | 1, 20 | 707,50 | 705,50 | 86155,759 | 2,359 | 7,424 | 86165,542 |
| | 37 57,62 | 1,15 | | | | | | | |
| | | | 1, 10 | 709,76 | 707,76 | 86156,527 | 1,983 | 7,381 | 86165,891 |
| 87,4 | 49 47,38 | 1,05 | | | | | | | |
| | | | 1,015 | 709,12 | 707,12 | 86156,517 | 1,688 | 7,352 | 86165,357 |
| | 3 1 36, 5 | 0,98 | | | | | | | |
| | | | 0, 94 | 710, 5 | 708, 5 | 86156,790 | 1,448 | 7,326 | 86165,564 |
| 87,3 | 13 27 | 0,90 | | | | | | | |
| 87,43 | Mean | | | | | | Rate of the Clock | | 86165,588 |
| | | | | | | | | | + 0, 99 |
| | | | | | | | | | 86166,578 |

Hygrometer 18°,6. Barometer { 30,008 / 30,000

Mean - 30,004

| Temp. | Time of coincidence. | Arc of vibration. | Mean Arc. | Interval in seconds. | Number of vibrations. | Observed vibrations in 24 hours. | Correction for Arc. | For Temperature. | Vibrations in 24 hours. |
|---|---|---|---|---|---|---|---|---|---|
| ° | h. m. s. | ° | ° | " | | | + | + | |
| 87,3 | 3 20 31 | 1,21 | | | | | | | |
| | | | 1, 16 | 717,37 | 715,37 | 86155,714 | 2,205 | 7,297 | 86165,216 |
| | 32 18,37 | 1,11 | | | | | | | |
| | | | 1, 07 | 710,00 | 708,00 | 86156,619 | 1,876 | 7,254 | 86165,749 |
| 87,1 | 44 08,37 | 1,03 | | | | | | | |
| | | | 0, 98 | 709,38 | 707,38 | 86156,407 | 1,574 | 7,225 | 86166,143 |
| | 55 57,75 | 0,93 | | | | | | | |
| | | | 0,895 | 712,12 | 710,12 | 86157,344 | 1,312 | 7,216 | 86165,872 |
| 87,054 | 7 49,87 | 0,86 | | | | | | | |
| 87,15 | Mean | | | | | Rate of the Clock | | | 86165,745 + ,990 |
| | | | | | | | | | 86166,735 |

*Table of the Results of the foregoing Experiments.*

SECOND SERIES.

| Day. 1821. | Time of the Experiment. | Mean Height of the Thermometer. | Mean Height of the Barometer. | Mean Height of the Hygrometer. | Number of Vibrations in 24 hours, at the temperature of 70° of Farenheit. |
|---|---|---|---|---|---|
| | | ° | Inch. | dry. | |
| April 18 | A. M. | 83,05 | 30,023 | | 86165,857 |
| | | 84,02 | 30,037 | 13,8 | 86165,951 |
| | | 85,04 | 30,044 | | 86166,032 |
| 19 | P. M. | 87,33 | 29,972 | | 86166,442 |
| | | 86,93 | 29,956 | 16,5 | 86166,246 |
| | | 86,43 | 29,950 | | 86166,382 |
| | A. M. | 83, 4 | 30,044 | | 86165,639 |
| | | 83,95 | 30,045 | 13,5 | 86165,900 |
| | | 84,77 | 30,043 | | 86165,970 |
| 20 | P. M. | 87,23 | 29,995 | | 86165,473 |
| | | 87, 0 | 29,979 | 17,1 | 86165,598 |
| | | 86,73 | 29,977 | | 86165,745 |
| | A. M. | 83, 5 | 30,059 | | 86165,029 |
| | | 84, 0 | 30,079 | 13,4 | 86165,150 |
| | | 84,75 | 30,085 | | 86165,626 |
| 21 | P. M. | 87,23 | 30,042 | | 86166,140 |
| | | 86,93 | 30,034 | 14 | 86166,151 |
| | | 86,73 | 30,031 | | 86166,179 |
| | A. M. | 83,53 | 30,063 | | 86165,253 |
| | | 83,83 | 30,065 | 17,4 | 86165,385 |
| | | 84, 4 | 30,070 | | 86165,805 |
| 22 | P. M. | 87,37 | 30,032 | | 86166,318 |
| | | 87, 1 | 30,021 | 17,3 | 86166,315 |
| | | 86,87 | 30,012 | | 86166,484 |
| | A. M. | 83,27 | 30,019 | 14,6 | 86167,304 |
| | | 83, 7 | 30,028 | | 86167,647 |
| 23 | P. M. | 87,43 | 30,012 | | 86166,578 |
| | | 87,15 | 30,004 | 18,4 | 86166,735 |
| Mean | | 85,49 | 30,258 | 15,6 | 86166,048 |

The height of the pendulum above the level of the sea was 27 feet; the distance in a direct line to the sea being about 4900 yards, or 2,784 miles. The country is flat; the nearest elevation being St. Thomas's Mount, which is 9950 yards, or 5,654 miles off, and rises but little above the ordinary level.* There is a range of low hills a short distance beyond St. Thomas's Mount; and the Pulicat Mountains, which are of considerable elevation, are 39 miles off. The soil about Madras is composed of sand and blue mud, and this to as great depths as the wells have been sunk. I do not recollect any rock having been found. I have therefore used 0,66 as a multiplier to 0,095, the correction for 27 feet, which gives 0,06 to be added to the number of beats in 24 hours.

The last correction required was for the buoyancy of the atmosphere. Having no information relative to the specific gravity of the pendulum, I was obliged to determine it in the best way the limited means in this country afforded. This was done with a balance at a dispensary, and with the aid of Mr. Bruce, the proprietor of the establishment. The Madras water drawn from wells in the Black town here, and conducted into the cisterns in the fort, is considered among the purest in the world. This was boiled, and strained into a tin trough prepared for the purpose; the pendulum also was securely and properly slung by means of brass wire, with the assistance of Mr. Gordon, jeweller, of this place. The water was at the same temperature with the atmosphere, and the experiments were made with every care. It may be unnecessary to detail them here; I shall therefore proceed to the result, which was as follows:

* About 150 feet above the level of the sea.

Thermometer 88°, barometer 30,064 inches, specific gravity of the pendulum 8,1085. Hence the specific gravity of the pendulum for the mean of the first series of observations, the thermometer being 83°,48, and barometer 30,121, was 8,02096, and the correction for the buoyancy of the atmosphere is +6,2075 vibrations. For the second series, the thermometer having been 85°,49, and barometer 30,258 inches, this correction is 6,220 vibrations. These corrections being applied to the number of vibrations before found, will give the true number of vibrations of the pendulum in 24 hours in vacuo at the level of the sea, the thermometer being 70°, and are as follow :—

By the first series of observations, 86172,3755. By the second series, 86172,328. The mean being 86172,352.

The length of the seconds pendulum in London, (latitude 51° 31′ 8″,4 N.) at the temperature of 70°, according to Captain KATER, is 39,142213 inches. Now, the pendulum of experiment used at Madras, made 86293,44 vibrations in 24 hours in London, latitude as before, and 83 feet above the level of the sea, the mean height of the thermometer being 67°,6, of the barometer 29,97 inches (vide Appendix). The correction for the height above the sea is 0,22, and that for the buoyancy of the atmosphere 6,566, both to be added: these corrections being applied, will give 86300,226 for the number of vibrations of the pendulum of experiment in 24 hours in vacuo at the level of the sea, the temperature being 70°. Now, 86300,226″ : 86400″ : : 39,142213 : 39,232772 the length of the pendulum of experiment.

Then 86172,375″ : 86400″ : : 39,232772 : 39,0863230087, the length of the seconds pendulum at Madras by the first series of observations.

Also, 86172,828 : 86400 : : 39,231772 : 39,026280447, the length of the seconds pendulum at Madras by the second series.

The mean of both is 39,026302 inches, being, according to Sir GEORGE SHUCKBURGH's scale, the length of the seconds pendulum by these experiments at Madras in lat. 13° 4′ 9″,1 N. at the level of the sea, in vacuo, and at a temperature of 70° of FAHRENHEIT.

Then comparing this length with 39,142213 inches, the length in latitude 51° 31′ 8″,4 N. as before stated, the diminution of gravity from the pole to the equator will be ,0052894, and the ellipticity $\frac{1}{297,56}$ nearly.

J. GOLDINGHAM.

*Madras,*
*May,* 1821.

# APPENDIX.

*The following are the Observations made by Captain* KATER *in England, before the Pendulum was sent out.*

July 25, 1820, in lat. 51° 31′ 8″.4

Clock losing 1ˢ,20 in a mean solar day. Barometer 29,83 Inches.

| Temp. | Time of coincidence. | Arc of vibration. | Mean Arc. | Interval in seconds. | Number of vibrations. | Observed vibrations in 24 hours. | Correction for Arc. | Vibrations in 24 hours. |
|---|---|---|---|---|---|---|---|---|
| ° | h. m. s. | ° | ° | | | | s. | |
| 67,4 | 1 5 25 | 1,17 | | | | | | |
| | | | 1,70 | 1629 | | | 1,88 | |
| | 32 34 | 0,97 | | | | | | |
| | | | 0,90 | 1634 | | | 1,33 | |
| | 59 48 | 0,84 | | | | | | |
| | | | 0,77 | 1639 | | | 0,97 | |
| | 2 27 7 | 0,71 | | | | | | |
| | | | 0,65 | 1642 | | | 0,69 | |
| 67,8 | 54 29 | 0,60 | | | | | | |
| 67,6 | Mean | | | 1636 | 1634 | 86293,18 | 1,22 | 86294.40 |

July 26.

Clock losing 1ˢ,22. Barometer 30,01 inch.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ° | h. m. s. | ° | ° | | | | | |
| 66,2 | 1 37 28 | 1,22 | | | | | | |
| | | | 1,18 | 1621 | | | 2,28 | |
| | 2 4 29 | 1,08 | | | | | | |
| | | | 0,99 | 1632 | | | 1,60 | |
| | 31 41 | 0,91 | | | | | | |
| | | | 0,84 | 1637 | | | 1,16 | |
| | 58 58 | 0,77 | | | | | | |
| | | | 0,71 | 1646 | | | 0,83 | |
| 66,8 | 3 26 24 | 0,65 | | | | | | |
| 66,5 | Mean | | | 1634 | 1632 | 86293,03 | 1,47 | 86294,50 |

July 27.

Clock losing 1',15. Barometer 30,01 inches.

| Temp. | Time of coincidence. | Arc of vibration. | Mean Arc. | Interval in seconds. | Number of vibrations. | Observed vibrations in 24 hours. | Correction for Arc. | Vibrations in 24 hours. |
|---|---|---|---|---|---|---|---|---|
| ° | h. m. s. | ° | ° | | | | s. | |
| 67,2 | 1 2 27 | 1,22 | | | | | | |
| | | | 1,12 | 1622 | | | 2,06 | |
| | 29 29 | 1,02 | | | | | | |
| | | | 0,94 | 1630 | | | 1,45 | |
| | 56 39 | 0,86 | | | | | | |
| | | | 0,79 | 1633 | | | 1,02 | |
| | 2 33 52 | 0,73 | | | | | | |
| | | | 0,67 | 1638 | | | 0,73 | |
| 67,8 | 51 10 | 0,62 | | | | | | |
| 67,5 | Mean | | | 1630,75 | 1628,75 | 86292,89 | 1,32 | 86294,21 |

July 28.

Clock losing 1,05. Barometer 30,01 inches.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ° | h. m. s. | ° | ° | | | | | |
| 67,8 | 0 50 41 | 1,19 | | | | | | |
| | | | 1,09 | 1614 | | | 1,95 | |
| | 1 17 35 | 1,00 | | | | | | |
| | | | 0,92 | 1624 | | | 1,39 | |
| | 44 39 | 0,84 | | | | | | |
| | | | 0,78 | 1630 | | | 1,00 | |
| | 2 11 49 | 0,73 | | | | | | |
| | | | 0,67 | 1627 | | | 0,73 | |
| 68,4 | 38 56 | 0,62 | | | | | | |
| 68,1 | Mean | | | 1623,75 | 1621,75 | 86292,53 | 1,27 | 86293,80 |

July 29.

Clock losing 1',07. Barometer 30,01 inches.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ° | h. m. s. | ° | ° | | | | | |
| 67,9 | 0 47 1 | 1,21 | | | | | | |
| | | | 1,11 | 1616 | | | 2,02 | |
| | 1 13 57 | 1,02 | | | | | | |
| | | | 0,94 | 1620 | | | 1,45 | |
| | 40 57 | 0,86 | | | | | | |
| | | | 0,79 | 1625 | | | 1,03 | |
| | 2 8 2 | 0,73 | | | | | | |
| | | | 0,68 | 1630 | | | 0,76 | |
| 68,8 | 35 12 | 0,63 | | | | | | |
| 68,3 | Mean | | | 1622,75 | 1620,75 | 86292,45 | 1,31 | 86293,76 |

Vibrations of the Pendulum at London.

| Date 1804. | Barometer. | Thermometer. | Vibrations in 24 hours. | Correction for Temperature. | Correct vibrations in a mean solar day at 70° |
|---|---|---|---|---|---|
| | Inch. | ° | | | |
| July 25 | 29,83 | 67,6 | 86294,40 | 1,02 | 86293,38 |
| 26 | 30,01 | 66,5 | 86294,50 | 1,48 | 86293,02 |
| 27 | 30,01 | 67,5 | 86294,21 | 1,06 | 86293,15 |
| 28 | 30,01 | 68,1 | 86293,80 | 0,30 | 86293,10 |
| 29 | 30,01 | 68,3 | 86293,76 | 0,72 | 86293,04 |
| Mean | 29,97 | 67,6 | | | 86293,14 |

From the above table it appears, that the pendulum makes 86293,14 vibrations in a mean solar day, in latitude 51° 31′ 8″,4 the temperature being 70°, and the height above the level of the sea 83 feet. The correction employed for temperature is 0,423 of a vibration for one degree. In computing the correction for the buoyancy of the atmosphere during the experiments, the temperature of 67°,6 must be used, the barometer being at 29,97 inches.

J. GOLDINGHAM.

XVI. *Account of an assemblage of Fossil Teeth and Bones of Elephant, Rhinoceros, Hippopotamus, Bear, Tiger, and Hyæna, and sixteen other animals; discovered in a cave at Kirkdale, Yorkshire, in the year 1821: with a comparative view of five similar caverns in various parts of England, and others on the Continent.* By the Rev. WILLIAM BUCKLAND, *F. R. S. F. L. S. Vice President of the Geological Society of London, and Professor of Mineralogy and Geology in the University of Oxford, &c. &c. &c.*

Read February 21, 1822.

HAVING been induced in December last to visit Yorkshire, for the purpose of investigating the circumstances of the cave at Kirkdale, near Kirby Moorside, about 25 miles N. N. E. of the city of York, in which a discovery was made last summer of a singular collection of teeth and bones, I beg to lay before the Royal Society the result of my observations on this new and interesting case, and to point out some important general conclusions that arise from it.

The facts I have collected, seem calculated to throw an important light on the state of our planet at a period antecedent to the last great convulsion that has affected its surface; and I may add, in limine, that they afford one of the most complete and satisfactory chains of consistent circumstantial evidence I have ever met with in the course of my geological investigations.

As I shall have frequent occasion to make use of the word

*diluvium*, it may be necessary to premise, that I apply it to those extensive and general deposits of superficial gravel, which appear to have been produced by the last great convulsion that has affected our planet; and that with regard to the indications afforded by geology of such a convulsion, I entirely coincide with the views of M. CUVIER, in considering them as bearing undeniable evidence of a recent and transient inundation.* On these grounds I have felt myself fully justified in applying the epithet *diluvial*, to the results of this great convulsion, of *antediluvial*, to the state of things immediately preceding it, and *postdiluvial*, or *alluvial*, to that which succeeded it, and has continued to the present time.

In detailing these observations I propose, first, to submit a short account of the geological position and relations of the rock in which the cavern alluded to is situated; to proceed, in the next place, to a description of the cavern itself; then to enter into that which will form the most important part of this communication, a particular enumeration of the animal remains there inhumed, and the very remarkable phenomena with which they are attended; to review the general inferences to which these phenomena lead; and conclude with a brief comparative account of analogous animal deposits in other parts of this country, and the Continent.

Kirkdale is situated (as may be seen by reference to the

* Analogous evidences to the same point, collected in this country from the state of the gravel beds and vallies in the midland parts of England, have recently been published by myself in a Paper on the Lickey Hill, in the second part of the fifth Volume of the Geological Transactions, and in the Appendix to an Inaugural Lecture I published at Oxford, in 1820. Another Paper of mine on similar evidences afforded by the vallies that intersect the coast of West Dorset and East Devonshire, will be published in the first part of the sixth Volume of the Geological Transactions.

annexed map, Plate XV.) about 25 miles N.N.E. of the city of York, between Helmsley and Kirby Moorside, near the point at which the east base of the Hambleton hills, looking towards Scarborough, subsides into the vale of Pickering, and on the S. extremity of the mountainous district known by the name of the Eastern and the Cleveland Moorlands.

The substratum of this valley of Pickering is a mass of stratified blue clay, identical with that which at Oxford and Weymouth reposes on a similar lime-stone to that of Kirkdale, and containing, subordinately, beds of inflammable bituminous shale, like that of Kimeridge, in Dorsetshire. Its south boundary is formed by the Howardian hills, and by the elevated escarpment of the chalk that terminates the Wolds towards Scarborough. Its north frontier is composed of a belt of lime-stone, extending eastward 30 miles from the Hambleton hills, near Helmsley, to the sea at Scarborough, and varying in breadth from 4 to 7 miles; this lime-stone is intersected by a succession of deep and parallel vallies, (here called dales) through which the following rivers, from the moorlands, pass down southwards to the vale of Pickering, viz. the Rye, the Rical, the Hodge Beck, the Dove, the Seven Beck, and the Costa; their united streams fall into the Derwent above New Malton, and their only outlet is by a deep gorge, extending from near this town down to Kirkham, the stoppage of which would at once convert the whole vale of Pickering into an immense inland lake; and before the excavation of which, it is probable, that such a lake existed, having its north border nearly along the edge of the belt of lime-stone just described, and at no great distance from the mouth of the cave at Kirkdale.

The position of the cave is at the south and lower extremity of one of these dales (that of the Rical Beck), at the point where it falls into the vale of Pickering, at the distance of about a furlong from the church of Kirkdale, and near the brow of the left flank of the valley, close to the road. This flank slopes towards the river at an angle of 25°, and the height of the brow of the slope above the water may be about 120 feet. (See Plate XVI. fig. 1.)

The rock perforated by the cave is referable to that portion of the oölite formation which, in the south of England, is known by the name of the Oxford oölite and coral rag: its organic remains are identical with those of the Heddington quarries near Oxford, but its substance is harder and more compact, and more interspersed with siliceous matter, forming irregular concretions, beds, and nodules of chert in the lime-stone, and sometimes entirely penetrating its coralline remains. The most compact beds of this lime-stone resemble the younger alpine lime-stone of Meillierie and Aigle, in Switzerland, and they alternate with and pass gradually into those of a coarser oölitic texture; and both varieties are stratified in beds from one to four feet thick. The cave is situated in one of the compact beds which lies between two others of the coarser oölitic variety; the latter vary in colour from light yellow to blue; the compact beds are of a dark grey passing to black, are extremely fetid, and full of corals and spines of the echinus cidaris. The compact portions of this oölite partake of the property common to compact lime-stones of all ages and formations, of being perforated by irregular holes and caverns intersecting them in all directions; the cause of these cavities has never been satisfactorily

ascertained: into this question (which is one of considerable difficulty in geology) it is foreign to my present purpose to enquire, any farther than to state that they were neither produced, enlarged, or diminished by the presence of the animals whose bones we now find in them.

The abundance of such caverns in the lime-stone of the vicinity of Kirkdale, is evident from the fact of the engulfment of several of the rivers above enumerated in the course of their passage across it from the eastern moorlands to the vale of Pickering, and it is important to observe, that the elevation of the Kirkdale cave, above the bed of the Hodge Beck, exceeding 100 feet, excludes the possibility of our attributing the muddy sediment we shall find it to contain, to any land flood or extraordinary rise of the waters of that or any other now existing river.

It was not till the summer of 1821, that the existence of any animal remains, or of the cavern containing them, had been suspected. At this time, in continuing the operations of a large quarry along the brow of the slope just mentioned, (see Plate XVI. fig. 1.) the workmen accidentally intersected the mouth of a long hole or cavern, closed externally with rubbish, and overgrown with grass and bushes. As this rubbish was removed before any competent person had examined it, it is not certain whether it was composed of diluvial gravel and rolled pebbles, or was simply the debris that had fallen from the softer portions of the strata that lay above it; the workmen, however, who removed it, and some gentlemen who saw it, assured me, that it was composed of gravel and sand. In the interior of the cave there was not a single rolled pebble, nor one bone, or fragment of bone, that bears the

slightest mark of having been rolled by the action of water. A few bits of lime-stone and roundish concretions of chert that had fallen from the roof and sides, were the only rocky fragments that occurred, with the exception of stalactite.

About 30 feet of the outer extremity of the cave have now been removed, and the present entrance is a hole in the perpendicular face of the quarry less than 5 feet square, which it is only possible for a man to enter on his hands and knees, and which expands and contracts itself irregularly from 2 to 7 feet in breadth and height, diminishing however as it proceeds into the interior of the hill. The cave is about 15 or 20 feet below the incumbent field, the surface of which is nearly level, and parallel to the stratification of the lime-stone, and to the bottom of the cave. Its main direction is E. S. E. but deviating from a straight line by several zigzags to the right and left (see Pl. XVI. fig. 3.); its greatest length is from 150 to 200 feet. In its interior it divides into several smaller passages, the extent of which has not been ascertained. In its course it is intersected by some vertical fissures, one of which is curvilinear, and again returns to the cave; another has never been traced to its termination; whilst the outer extremity of a third, is probably seen in a crevice or fissure that appears on the face of the quarry, and which closes upwards before it leaves the body of the lime-stone. By removing the sediment and stalactite that now obstruct the smaller passages, a farther advance in them may be rendered practicable. The half corroded fragments of corals, of spines of echini and other organic remains, and the curious ledges of lime-stone and nodules of chert that project along the sides and roof of the cave, together with the small

grooves and pits that cover great part of its interior, show that there was a time when its dimensions were less than at present; though they fail to prove by what cause it was originally produced. There are but two or three places in which it is possible to stand upright, and these are where the cavern is intersected by the fissures; the latter of which continue open upwards to the height only of a few feet, when they gradually close, and terminate in the body of the lime-stone: they are thickly lined with stalactite, and are attended by no fault or slip of either of their sides. Both the roof and floor, for many yards from the entrance, are composed of horizontal strata of lime-stone, uninterrupted by the slightest appearance of fissure, fracture, or stony rubbish of any kind; but farther in, the roof and sides become irregularly arched, presenting a very rugged and grotesque appearance, and being studded with pendent and roundish masses of chert and stalactite; the bottom of the cavern is visible only near the entrance; and its irregularities, though apparently not great, have been filled up throughout to a nearly level surface, by the introduction of a bed of mud or sediment, the history of which, and also of the stalactite, I shall presently describe. (See Plate XVI. fig. 3).

The fact already mentioned of the engulphment of the Rical Beck, and other adjacent rivers, as they cross the lime-stone, showing it to abound with many similar cavities to those at Kirkdale, renders it likely that, hereafter, similar deposits of bones may be discovered in this same neighbourhood; but accident alone can lead to such discovery, as it is probable the mouths of these caverns are buried under diluvian sand and gravel, or post-diluvian detritus; so that nothing but their

casual intersection by some artificial operations, will lead to the knowledge of their existence; and in this circumstance, we also see a reason why so few caverns of this kind have hitherto been discovered, although it is probable that many such may exist.

In all these cases, the bones found in caverns are never mineralised, but simply in the state of grave bones, or incrusted by stalactite; and have no farther connection with the rocks themselves, than that arising from the accident of having been lodged in their cavities, at periods long subsequent to the formation and consolidation of the strata in which these cavities occur.

On entering the cave at Kirkdale (see Plate XVI. fig. 1), the first thing we observe is a sediment of mud, covering entirely its whole bottom to the average depth of about a foot, and entirely covering and concealing the subjacent rock, or actual floor of the cavern. Not a particle of mud is found attached either to the sides or roof; nor is there a trace of it adhering to the sides or upper portions of the transverse fissures, or any thing to suggest the idea that it entered through them. The surface of this sediment when the cave was first entered was nearly smooth and level, except in those parts where its regularity had been broken by the accumulation of stalagmite above it, or ruffled by the dripping of water: its substance is argillaceous and slightly micaceous loam, composed of such minute particles as would easily be suspended in muddy water, and mixt with much calcareous matter, that seems to have been derived in part from the dripping of the roof, and in part from comminuted bones.

Above this mud, on advancing some way into the cave, the

roof and sides are seen to be partially studded and cased over with a coating of stalactite, which is most abundant in those parts where the transverse fissures occur, but in small quantity where the rock is compact and devoid of fissures. Thus far it resembles the stalactite of ordinary caverns; but on tracing it downwards to the surface of the mud, it was there found to turn off at right angles from the sides of the cave, and form above the mud a plate or crust, shooting across like ice on the surface of water, or cream on a pan of milk. (See Plate XVI. fig. 2). The thickness and quantity of this crust varied with that found on the roof and sides, being most abundant, and covering the mud entirely where there was much stalactite on the sides, and more scanty in those places where the roof presented but little: in many parts it was totally wanting both on the roof and surface of the mud and subjacent floor. Great portion of this crust had been destroyed in digging up the mud to extract the bones; it still remained, however, projecting partially in some few places along the sides; and in one or two, where it was very thick, it formed, when I visited the cave, a continuous bridge over the mud entirely across from one side to the other. In the outer portion of the cave, there was a mass of this kind which had been accumulated so high as to obstruct the passage, so that a man could not enter till it had been dug away.

These horizontal incrustations have been formed by the water which, trickling down the sides, was forced to ooze off laterally as soon as it came into contact with the mud; in other parts, where it fell in drops from the roof, stalagmitic accumulations have been raised on its surface, some of which are very large, but more commonly they are of the size and

shape of a cow's pap, a name which the workmen have applied to them. There is no alternation of mud with any repeated beds of stalactite, but simply a partial deposit of the latter on the floor beneath it; and it was chiefly in the lower part of the sediment above described, and in the stalagmitic matter beneath it, that the animal remains were found: its substance contains no black earth or admixture of animal matter, except an infinity of extremely minute particles of undecomposed bone. In the whole extent of the cave, only a very few large bones have been discovered that are tolerably perfect; most of them are broken into small angular fragments and chips, the greater part of which lay separately in the mud, whilst others were wholly or partially invested with stalactite; and some of the latter united with masses of still smaller fragments and cemented by the stalactite, so as to form an osseous breccia, of which I have specimens.

The effect of this mud in preserving the bones from decomposition has been very remarkable; some that had lain a long time before its introduction were in various stages of decomposition; but even in these, the farther progress of decay appears to have been arrested by it; and in the greater number, little or no destruction of their form, and scarcely any of their substance, has taken place. I have found on immersing fragments of these bones in an acid till the phosphate and carbonate of lime were removed, that nearly the whole of their original gelatine has been preserved. Analogous cases of the preservative powers of diluvial mud occur on the coast of Essex, near Walton, and at Lawford, near Rugby, in Warwickshire. Here the bones of the same species of elephant, rhinoceros, and other diluvial animals occur in a state of freshness and freedom from decay, nearly equal

to those in the cave at Kirkdale, and this from the same cause, viz. their having been protected from the access of atmospheric air, or the percolation of water, by the argillaceous matrix in which they have been imbedded: whilst similar bones that have lain the same length of time in diluvial sand, or gravel, and been subject to the constant percolation of water, have lost their compactness and strength and great part of their gelatine, and are often ready to fall to pieces on the slightest touch; and this where beds of clay and gravel occur alternating in the same quarry, as at Lawford.

The workmen on first discovering the bones at Kirkdale, supposed them to have belonged to cattle that died by a murrain in this district a few years ago, and they were for some time neglected, and thrown on the roads with the common lime-stone; they were at length noticed by Mr. Harrison, a medical gentleman of Kirby Moorside, and have since been collected and dispersed amongst so many individuals, that it is probable nearly all the specimens will in a few years be lost, with the exception of such as may be deposited in public collections. By the kindness and liberality of the Bishop of Oxford (to whom I am also indebted for my first information of the discovery of this cave) and of C. Duncombe, Esq. and Lady Charlotte Duncombe, of Duncombe Park, a nearly complete series of the teeth of all these animals has been presented to the Museum at Oxford; whilst a still better collection both of teeth and bones is in the possession of J. Gibson, Esq. of Stratford in Essex, to whose exertions we owe the preservation of many valuable specimens, and who is about to present a series of them to our public collections in London. W. Salmond, Esq. also, since I visited Kirkdale in December last, has been engaged with much zeal and acti-

vity in measuring and exploring new branches of the cave, and making large collections of the teeth and bones, from which I understand he also intends to enrich our public cabinets in the metropolis. I am indebted to him for the annexed ground plan of the cave, and its ramifications, (Plate XVI. fig. 3). Drawings by Mr. Clift, of some of the most perfect of Mr. Gibson's specimens, have been sent to M. Cuvier, for the new edition of his work on fossil animals; copies of these have been made for me by Miss Mokland, and appear in the annexed plates, with many other drawings, for which I am indebted to the pencil of Miss Dundonbe; and the Rev. George Young, and Mr. Bird of Whitby, in their History of the Geology of the coast of Yorkshire, have given engravings of some teeth that remain in their possession.

It appears that the teeth and bones which have as yet been discovered in the cave at Kirkdale, are referable to the following twenty-two species of animals.

7 Carnivora. Hyæna, Tiger, Bear, Wolf, Fox, Weasel, and an unknown animal of the size of a Wolf. (See Plates XVII. XVIII. XIX. XX.)

4 Pachydermata. Elephant, Rhinoceros, Hippopotamus and Horse. (See Plate XXI.)

4 Ruminantia. Ox, and three species of Deer. (See Plates XXII. XXIII.)

3 Rodentia. Rabbit, Water-rat and Mouse. (See Plate XXIV. XXV.)

4 Birds. Raven, Pigeon, Lark, and a small species of Duck, resembling the anas sponsor, or summer Duck. (See Plate XXV.)

The bottom of the cave, on first removing the mud, was

found to be strewed all over like a dog kennel, from one end to the other, with hundreds of teeth and bones, or rather broken and splintered fragments of bones, of all the animals above enumerated; they were found in greatest quantity near its mouth, simply because its area in this part was most capacious; those of the larger animals, elephant, rhinoceros, &c. were found co-extensively with all the rest, even in the inmost and smallest recesses, (see Plate XVI. fig. 3). Scarcely a single bone has escaped fracture, with the exception of the astragalus, and other hard and solid bones of the tarsus and carpus joints, and of the toes (see Plate XXIV. fig. 1 to 5, and fig. 7 to 10, and Plate XIX. fig. 5 to 12). On some of the bones marks may be traced, which, on applying one to the other, appear exactly to fit the form of the canine teeth of the hyæna that occur in the cave. The hyænas' bones have been broken, and apparently gnawed equally with those of the other animals. Heaps of small splinters, and highly comminuted, yet angular fragments of bone, mixed with teeth of all the varieties of animals above enumerated, lay in the bottom of the den, occasionally adhering together by stalactite, and forming, as has been before mentioned, an osseous breccia. Many insulated fragments also are wholly or partially enveloped with stalactite, both externally and internally. Not one skull is to be found entire; and it is so rare to find a large bone of any kind that has not been more or less broken, that there is no hope of obtaining materials for the construction of any thing like a skeleton. The jaw bones also, even of the hyænas, are broken like the rest; and in the case of all the animals, the number of teeth and of solid bones of the tarsus and carpus,

is more than twenty times as great as could have been supplied by the individuals whose other bones we find mixed with them.

Fragments of jaw bones are by no means common; the greatest number I saw belong to the deer, hyæna, and water-rat, and retain their teeth; in all the jaws both teeth and bone are in an equal state of high preservation, and show that their fracture has been the effect of violence, and not of natural decay. I have seen but ten fragments of deers' jaws, and about forty of hyænas', and as many of rats. (See Plate XVIII. fig. 2, 3, and Plate XVII. fig. 3, 4, 5.) The ordinary fate of the jaw bones, as of all the rest, appears to have been to be broken to pieces.

The greatest number of teeth are those of hyænas, and the ruminantia. Mr. GIBSON alone collected more than 300 canine teeth of the hyæna, which at the least must have belonged to 75 individuals, and they are in the same proportion in other collections. The only remains that have been found of the tiger species (see Plate XX. fig. 5, 6, 7), are two large canine teeth, each 4 inches in length, and one molar tooth, exceeding in size that of the largest lion or Bengal tiger. There is one tusk only of a bear (see Plate XX. fig. 1), which exactly resembles those of the extinct ursus spelæus of the caves of Germany, the size of which M. CUVIER says must have equalled that of a large horse. Of the wolf and fox there are many teeth (see Plate XX. fig. 8 to 18), and others belonging to an animal which I cannot ascertain: it seems to have been nearly allied to the wolf, but the teeth are much thinner, and less strong. (See Plate XX. fig. 20 to 27). A few jaws and teeth have also been found belonging to the

weasel. (Plate XX. fig. 28, 29.) Teeth of the larger pachydermatous animals are not abundant. I have information of about ten elephants' teeth, but of no tusk; and as very few of these teeth exceed three inches in their longest diameter, they must have belonged to very young animals. (See Plate XXI. fig. 1 and 2). I have seen but six molar teeth of the hippopotamus, and a few fragments of its canine and incisor teeth; some of which latter are in the possession of Mr. THORPE, of York. Teeth of the rhinoceros are not so rare. I have seen 40 or 50, and some of them extremely large ones, and apparently from aged animals. I have heard of only two or three teeth belonging to the horse. Of the teeth of deer there are at least three species (see Plate XXII. fig. 9, 11, 13), the smallest being very nearly of the size and form of those of a fallow deer, the largest agreeing in size, but differing in form from those of the modern elk; and a third being of an intermediate size, and approaching that of a large stag or red deer. I have not ascertained how many species there are of ox, but apparently there are at least two. But the teeth which occur perhaps in greatest abundance, are those of the water-rat (see Pl. XXV. fig. 1 to 5, and 11 to 18;) for in almost every specimen I have collected or seen of the osseous breccia, there are teeth or broken fragments of the bones of this little animal mixed with and adhering to the fragments of all the larger bones. These rats may be supposed to have abounded on the edge of the lake, which I have shown probably to have existed at that time in this neighbourhood: there are also a few teeth and bones of rabbits and mice. (Plate XXIV. fig. 14, 15, 16, 17, 18, and Plate XXV. fig. 7, 8, 9, 10).

Besides the teeth and bones already described, the cave

contained also remains of horns of at least two species of deer, (see Plate XXIII. fig. 3, 4, and 5.) One of these resembles the horn of the common stag or red deer, the circumference of the base measuring 9¼ inches, which is precisely the size of our largest stag. A second (fig. 4.) measures 7¼ inches at the same part, and both have two antlers, that rise very near the base. In a smaller species the lowest antler is 3½ inches above the base, the circumference of which is 8 inches, (see fig. 5.) No horns are found entire, but fragments only, and these apparently gnawed to pieces like the bones: their lower extremity nearest the head is that which has generally escaped destruction: and it is a curious fact, that this portion of all the horns I have seen from the cave, shows, by the rounded state of the base, that they had fallen off by absorption or necrosis, and been shed from the head on which they grew, and not broken off by violence.

It must already appear probable, from the facts above described, particularly from the comminuted state and apparently gnawed condition of the bones, that the cave at Kirkdale was, during a long succession of years, inhabited as a den by hyænas, and that they dragged into its recesses the other animal bodies whose remains are found mixed indiscriminately with their own; and this conjecture is rendered almost certain by the discovery I made, of many small balls of the solid calcareous excrement of an animal that had fed on bones, resembling the substance known in the old Materia Medica by the name of album græcum (see Plate XXIV. fig. 6.): its external form is that of a sphere, irregularly compressed, as in the fæces of sheep, and varying from half an inch to an inch in diameter; its colour is yellowish white, its fracture

is usually earthy and compact, resembling steatite, and sometimes granular; when compact, it is interspersed with minute cellular cavities: it was at first sight recognised by the keeper of the Menagerie at Exeter Change, as resembling, both in form and appearance, the fæces of the spotted or Cape Hyæna, which he stated to be greedy of bones, beyond all other beasts under his care. This information I owe to Dr. Wollaston, who has also made an analysis of the substance under discussion, and finds it to be composed of the ingredients that might be expected in fæcal matter derived from bones, viz. phosphate of lime, carbonate of lime, and a very small proportion of the triple phosphate of ammonia and magnesia; it retains no animal matter, and its originally earthy nature and affinity to bone, will account for its perfect state of preservation.

I do not know what more conclusive evidence than this can be added to the facts already enumerated, to show that the hyænas inhabited this cave, and were the agents by which the teeth and bones of the other animals were there collected; it may be useful therefore to consider, in this part of our enquiry, what are the habits of modern hyænas, and how far they illustrate the case before us.

The modern hyæna (of which there are only three known species, all of them smaller and different from the fossil one) is an inhabitant exclusively of hot climates; the most savage, or striped species, abounds in Abyssinia, Nubia, and the adjacent parts of Africa and Asia. The less ferocious, or spotted one, inhabits the Cape of Good Hope, and lives principally on carrion. In bony structure the latter approaches more nearly than the former to the fossil species: to these M. Cuvier adds a third, the red hyæna, which is very rare.

The structure of these animals places them in an intermediate class between the cat and dog tribes; not feeding, like the former, almost exclusively on living prey, but like the latter, being greedy also of putrid flesh and bones:* their love of putrid flesh induces them to follow armies, and dig up human bodies from the grave. They inhabit holes which they dig in the earth, and chasms of rocks; are fierce, and of obstinate courage, attacking stronger quadrupeds than themselves, and even repelling lions. Their habit of digging human bodies from the grave, and dragging them to their den, and of accumulating around it the bones of all kinds of animals, is thus described by BUSBEQUIUS, where he is speaking of the Turkish mode of burial in Anatolia, and their custom of laying large stones upon their graves to protect them from the Hyænas. "Hyæna regionibus iis satis frequens; sepulchra suffodit, extrahitque cadavera, portatque ad suam speluncam; juxta quam videre est ingentem cumulum ossium humanorum 'veterinariorum'† et reliquorum omne genus animalium." (Busbeq. Epist. 1. Leg. Turc.) BROWN, also, in his Travels to Darfur, describes the Hyænas' manner of taking off their prey in the following words:—"they come in herds of six, eight, and often more, into the villages at night, and carry off with them whatever they are able to master; they will kill dogs and asses even within the enclosure of houses, and fail not to assemble wherever a dead camel or

* It is quite impossible to mistake the jaw of any species of hyæna for that of the wolf or tiger kind; the latter having three molar teeth only in the lower jaw, and the former seven; whilst all the hyæna tribe have four. (See Plate XVIII. fig. 1, 2, 3.)

† Veterinam bestiam jumentum CATO appellavit a vehendo: (quasi vehetorinus vel veterinus.) Pomp. Fest.

other animal is thrown, which, acting in concert, they sometimes drag to a prodigious distance." SPARMAN and PENNANT mention that a single hyæna has been known to carry off a living man or woman in the vicinity of the Cape.

The strength of the hyæna's jaw is such, that in attacking a dog, he begins by biting off his leg at a single snap. The capacity of his teeth, for such an operation, is sufficiently obvious from simple inspection, and had long ago attracted the attention of the early naturalists; and, consistent with this strength of teeth and jaw, is the state of the muscles of his neck, being so full and strong, that in early times this animal was fabled to have but one cervical vertebra. They live by day in dens, and seek their prey by night, having large prominent eyes, adapted, like those of the rat and mouse, for seeing in the dark. To animals of such a class, our cave at Kirkdale would afford a most convenient habitation, and the circumstances we find developed in it are entirely consistent with the habits above enumerated.

It appears from the researches of M. CUVIER, that the fossil hyæna was nearly one third larger than the largest of the modern species, that is, the striped or Abyssinian; but, in the structure of its teeth, more nearly resembled that of the Cape animal. (See Plate XVIII. fig. 1, 2, 3.) Its muzzle also was shorter and stronger than in either of them, and consequently its bite more powerful. The length of the largest modern hyæna noticed is 5 feet 9 inches.

The fossil species has been found on the Continent in situations of two kinds, both of them consistent with the circumstances under which it occurs in Yorkshire, and, on comparing the jaws and teeth of the latter with those of the former

engraved in M. CUVIER's *Recherches sur les ossemens fossiles*, I find them to be absolutely identical. The two situations are caverns and diluvian gravel.

1. In Franconia, a few bones of hyæna were found mixt with those of an enormous number of bears, in the cave of Gailenreuth.
2. At Muggendorf, in a similar cave.
3. At Bauman, in ditto.
4. At Fouvent, near Gray, in the department of Doubes, bones of hyæna were found mixt with those of the elephant and horse in a fissure of lime-stone rock, which, like that at Kirkdale, was discovered by the accidental digging away of the rock in a garden.
5. At Canstadt, in the valley of the Necker, A. D. 1700, hyænas' bones were found mixt with those of the elephant, rhinoceros, and horse, and with rolled pebbles, in a mass of yellowish clay.
6. Between Hahldorf and Reiterbuck, on the surface of the hills that bound the valley of Eichstadt in Bavaria. These were buried in a bed of sand.

The four first of these cases appear to have been dens, like the cave at Kirkdale; the two latter are deposits of diluvian detritus, like the surface gravel beds of England, in which similar remains of all the other animals have been found, excepting hyænas.

It has been observed when speaking of the den, that the bones of the hyænas are as much broken to pieces as those of the animals that formed their prey; and hence we must infer, that the carcases even of the hyænas themselves, were eaten up by their survivors. Whether it be the habit of modern

hyænas to devour those of their own species that die in the course of nature; or under the pressure of extreme hunger to kill and eat the weaker of them, is a point on which it is not easy to obtain positive evidence. Mr. Brown however asserts, in his journey to Darfur, "that it is related of the hyænas, that upon one of them being wounded, his companions instantly tear him to pieces and devour him." It seems therefore in the highest degree probable, that the mangled relics of hyænas that lie indiscriminately scattered and equally broken with the bones of other animals in the cave of Kirkdale, were reduced to this state by the agency of the surviving individuals of their own species.

A large proportion of the hyænas' teeth bear marks of extreme old age, some being abraded to the very sockets, and the majority having lost the upper portion of their coronary part, and having fangs extremely large: these probably died in the den from mere old age: and if we compare the lacerated condition of the bones that accompany them, with the state of the teeth thus worn down to the very stumps, notwithstanding their prodigious strength, we find in the latter the obvious instruments by which the former were thus comminuted. A great number of other teeth appear to have belonged to young hyænas, for the fangs are not developed, and the points and edges of the crown not the least worn down. I have a fragment of the jaw of an hyæna which died so young, that the second set of its teeth had not been protruded, but were in the act of forming within the jaw. (See Plate XIX. fig. 3, 4.) Others are in various stages of advancement towards maturity; and the proportion of these is too great for us to attribute them to animals that may have

died in early life from accident or disease. It seems more probable, and the idea is confirmed by the above statement of Mr. Brown, and by the fact of the hyænas' bones in the den being gnawed and broken to pieces equally with the rest, that they were occasionally killed and devoured by the stronger individuals of their own species.

But, besides the evidence their teeth afford to show that the animals died at various periods of life, they present other appearances (and so likewise do the bones), of having passed through different stages and gradations of decay, arising from the different length of time they had lain exposed in the bottom of the den, before the muddy sediment entered, which, since its introduction, has preserved them from farther decomposition. This observation applies equally to all the animals. I have portions of bone and teeth that are so much decomposed as to be ready to fall to pieces by the slightest touch; these had probably lain a long time unprotected in the bottom of the den; others still older may have entirely perished; but the majority both of teeth and fragments of bone are in a state of the highest preservation; and many thousands have been collected and carried away since the cave was discovered. In all cases the degree of decay is equal in the teeth and jaw bones, or fragments of jaws, to which they are attached.

In many of the most highly preserved bones and teeth, there is a curious circumstance, which, before I visited Kirkdale, had convinced me of the existence of the den, viz. a partial polish and wearing away to a considerable depth of one side only; many straight fragments of the larger bones have one entire side, or the fractured edges of one side rubbed

down and worn completely smooth, whilst the opposite side and ends of the same bone are sharp and untouched; in the same manner as the upper portions of pitching stones in the street become rounded and polished, whilst their lower parts retain the exact form and angles which they possessed when first laid down. This can only be explained by referring the partial destruction of the solid bone to friction from the continual treading of the hyænas, and rubbing of their skin on the side that lay uppermost in the bottom of the den. In many of the smaller and curved bones, also, particularly in those of the lower jaw, (see Plate XIX. fig. 1 and 2.) the convex surface only is uniformly that which has been worn down and polished, whilst the ends and concave surface have suffered no kind of change or destruction, (Plate XIX. fig. 3 and 4.): and this also admits of a similar explanation; for the curvature of the bone would allow it to rest steady under constant treading only in this position; as long as the concave surface was uppermost, pressure on either extremity would cause it to tilt over and throw the convex side upwards; and this done, the next pressure would cause its two extremities to sink into any soft substance that lay beneath, and give it a steady and fixed position. Such seems to have been the process by which the curved fragments I allude to, have not only received a partial polish on the convex side only, but have been submitted to so much friction, that in several instances more than one-fourth of the entire thickness of the bone, and a proportionate quantity of the outer side of the fangs and body of the teeth, have been entirely worn away. (See Plate XIX. fig. 1.) I can imagine no other means than the repeated touch of the living hyænas' feet and skin, by

which this partial wearing away and polish can have been produced:* for the process of rolling by water would have made pebbles of them, or at least would have broken off the edges of the teeth and delicate points of the fractured extremities of the bone, which still remain untouched and sharp.

I have already stated, that the greatest number of teeth (those of the hyæna excepted) belong to the ruminating animals; from which it is to be inferred that they formed the ordinary prey of the hyænas. I have also to add, that very few of the teeth of these animals bear marks of age; they seem to have perished by a violent death in the vigour of life. With respect to the horns of deer that appear to have fallen off by necrosis, it is probable that the hyænas found them thus shed, and dragged them home for the purpose of gnawing them in their den; and to animals so fond of bones, the spongy interior of horns of this kind would not be unacceptable. I found a fragment of stags' horn in so small a recess of the cave, that it never could have been introduced, unless singly, and after separation from the head; and near it was the molar tooth of an elephant. I have seen no remains of horns of oxen, and perhaps there are none, for the bony portion of their interior being of a porous spongy nature, would probably have been eaten by the hyænas, whilst the outer case, being of a similar composition to hair and hoofs,

* I have been informed by an officer in India, that passing by a tiger's den in the absence of the tiger, he examined the interior, and found in the middle of it a large portion of stone on which the tiger reposed, to be worn smooth and polished by the friction of his body. The same thing may be seen on marble steps and altars, and even metallic statues in places of worship that are favourite objects of pilgrimage: they are often deeply worn and polished by the knees, and even lips of pilgrims, to a degree that, without experience of the fact, we could scarcely have anticipated.

would not long have escaped total decomposition. For the same reason the horn of the rhinoceros, being merely a mass of compacted hair-like fibres, has never been found fossil in gravel beds with the bones of that animal, nor does it occur in the cave at Kirkdale. I have been told that sheeps' horns laid on land for manure will be consumed in ten or a dozen years; the calcareous matter of bone being nearly allied to lime-stone, is the only portion of animal bodies that occurs in a fossil state, unless when preserved, like the Siberian elephant, of the same extinct species with that of Kirkdale, by being frozen in ice, or buried in peat.

The extreme abundance of the teeth of water rats has also been alluded to; and though the idea of hyænas eating rats may appear ridiculous, it is consistent with the omnivorous appetite of modern hyænas; nor is the disproportion in size of the animal to that of its prey, greater than that of wolves and foxes, which are supposed by Captain PARRY to feed chiefly on mice during the long winters of Melville Island. Our largest dogs eat rats and mice; jackalls occasionally prey on mice, and dogs and foxes will eat frogs. It is probable, therefore, that neither the size nor aquatic habit of the water rat would secure it from the hyænas. They might occasionally also have eaten mice, weasels, rabbits, foxes, wolves, and birds; and in masticating the bodies of these small animals with their coarse conical teeth, many bones and fragments of bone would be pressed outwards through their lips, and fall neglected to the ground.

The occurrence of birds' bones may be explained by the probability of the hyænas finding them dead, and taking them home, as usual, to eat in their den: and the fact, that four

of the only five bones of birds I have seen from Kirkdale are those of the ulna, may have arisen from the position of the quill feathers on it, and the small quantity of fleshy matter that exists on the outer extremity of the wing of birds; the former affording an obstacle, and the latter no temptation to the hyænas to devour them. Two of the five bones here mentioned (see Plate XXV. fig. 19 to 29), in size and form, and the position of the points at the base of the quills, exactly resemble the ulna of a raven; a third approaches as closely to the Spanish runt, which is one of the largest of the pigeon tribe; a fourth bone is the right ulna of a lark; and a fifth, the coracoid process of the right scapula of a small species of duck resembling the Anas sponsor, or summer duck.*

With respect to the bear and tiger, the remains of which are extremely rare, and of which the teeth that have been found (see Plate XX. fig. 1, 5, 6, and 7), indicate a magnitude equal to the great Ursus spelæus of the caves of Germany, and of the largest Bengal tiger, it is more probable that the hyænas found their dead carcases and dragged them to the den, than that they were ever joint tenants of the same cavern. It is however obvious that they were all at the same time inhabitants of antediluvian Yorkshire.

In the case of such minute and burrowing animals as the mouse and weasel, and perhaps the rabbit and fox, it is possible that some of them may have crept into the cave by undiscovered crevices, and there died since the stoppage of its

* For my knowledge of these, and many other bones I have from Kirkdale, I am indebted to a careful examination and comparison of them made by Mr. BROOKS, in his most valuable collection of osteological preparations. Mr. CLIFT also has kindly assisted me at the Royal College of Surgeons in furtherance of the same object.

mouth; and in such case their bones would have been found lying on the surface of the mud before it was disturbed by digging: as no observations were made in season as to this point, it must remain unsettled, till the opening of another cave may give opportunity for more accurate investigation. This uncertainty, however, applies not to any of the extinct species, or to the larger animals, whose habit it is not to burrow in the ground, nor even to those of the smaller ones, *e. g.* the water rat, fragments of whose bones and teeth are found imbedded in the antediluvian stalagmite, and cemented by it both to the exterior and internal cavities of bones belonging to the hyænas and other extinct species, which, beyond all doubt, were lodged in the den before the period of the introduction of the mud. Should it turn out that since this period the cave has been accessible to foxes and weasels, it is possible that some of the birds also may have been introduced by them. The evidence of this, however, rests on a fact not yet carefully ascertained, viz. whether the bones in question were buried, like those of the extinct animals, beneath the mud, or lay on its surface; the state of one of the ravens' bones, containing stalagmite in its central cavity (see Plate XXV. fig. 22, 23), seems to indicate high antiquity; and the quarryman, who was the first to enter the cave, assured me, that he has never seen a single bone of any kind on the surface, nor without digging into the substance of the mud.

As ruminating animals form the ordinary food of beasts of prey, it is not surprising that their remains should occur in such abundance in the cave (see Plate XXII. fig. 1 to 14); but it is not so obvious by what means the bones and teeth of the elephant, rhinoceros, and hippopotamus, were conveyed

thither (see Plate XXI. fig. 1 to 6, and 8 to 10.). On the one hand, the cave is in general of dimensions so contracted (often not exceeding three feet in diameter), that it is impossible that living animals of these species could have found an entrance, or the entire carcases of dead ones been floated into it; moreover, had the bones been washed in, they would probably have been mixed with pebbles and rounded equably by friction, which they are not: on the other hand, it is foreign to the habits of the hyæna to prey on the larger pachydermata, their young perhaps excepted. No other solution of the difficulty presents itself to me, than that the remains in question are those of individuals that died a natural death; for though an hyæna would neither have had strength to kill a living elephant or rhinoceros, or to drag home the entire carcase of a dead one, yet he could carry away, piecemeal, or acting conjointly with others, fragments of the most bulky animals that died in the course of nature, and thus introduce them to the inmost recesses of his den.

Should it be asked why, amidst the remains of so many hundred animals, not a single skeleton of any kind has been found entire, we see an obvious answer, in the power and known habit of hyænas to devour the bones of their prey; and the gnawed fragments on the one hand, and album græcum on the other, afford double evidence of their having largely gratified this natural propensity: the exception of the teeth and numerous small bones of the lower joints and extremities, that remain unbroken, as having been too hard and solid to afford inducement for mastication, is entirely consistent with this solution. And should it be further asked, why we do not find, at least, the entire skeleton of the one or

more hyænas that died last, and left no survivors to devour them; we find a sufficient reply to this question, in the circumstance of the probable destruction of the last individuals by the diluvian waters: on the rise of these, had there been any hyænas in the den, they would have rushed out, and fled for safety to the hills; and if absent, they could by no possibility have returned to it from the higher levels: that they did so perish on the continent is obvious, from the discovery of their bones in the diluvial gravel of Germany, as well as in the caves. The same circumstance will also explain the reason why there are no bones found on the outside of the Kirkdale cave, as described by Busbequius on the outside of the hyænas' dens in Anatolia; for every thing that lay without, on the antediluvian surface, must have been swept far away, and scattered by the violence of the diluvian waters; and there is no reason for believing that hyænas, or any other animals whatever, have occupied the den at any period subsequent to that catastrophe.

Although the evidence to prove the cave to have been inhabited as a den by successive generations of hyænas, appears thus direct, it may be as well to consider what other hypotheses may be suggested, to explain the collection of bones assembled in it.

1st. It may be said, that the various animals had entered the cave spontaneously to die, or had fled into it as a refuge from some general convulsion: but the diameter of the cave, as has been mentioned before, compared with the bulk of the elephant and rhinoceros, renders this solution impossible as to the larger animals; and with respect to the smaller, we can imagine no circumstances that would collect together,

spontaneously, animals of such dissimilar habits as hyænas, tigers, bears, wolves, foxes, horses, oxen, deer, rabbits, water-rats, mice, weasels, and birds.

2d. It may be suggested, that they were drifted in by the waters of a flood: if so, either the carcases floated in entire; or the bones alone were drifted in after separation from the flesh: in the first of these cases, the larger carcases, as we have already stated, could not have entered at all; and of the smaller ones, the cave could not have contained a sufficient number to supply one-twentieth part of the teeth and bones; moreover, the bones would not have been broken to pieces, nor in different stages of decay. And had they been washed in by a succession of floods, we should have had a succession of beds of sediment and stalactite, and the cave would have been filled up by the second or third repetition of such an operation as that which introduced the single stratum of mud, which alone occurs in it. On the other hypothesis, that they were drifted in after separation from the flesh, they would have been mixed with gravel, and at least slightly rolled on their passage; and it would still remain to be shown by what means they were split and broken to pieces, and the disproportion created which exists between the numbers of the teeth and bones. They could not have fallen in through the fissures, for these are closed upwards in the substance of the rock, and do not reach to the surface.

The 3rd, and only remaining hypothesis that occurs to me is, that they were dragged in for food by the hyænas, who caught their prey in the immediate vicinity of their den; and as they could not have dragged it home from any very great distance, it follows, that the animals they fed on all lived

and died not far from the spot where their remains are found.

The accumulation of these bones, then, appears to have been a long process, going on during a succession of years, whilst all the animals in question were natives of this country. The general dispersion of similar bones through the diluvian gravel of high latitudes, over great part of the northern hemisphere, shows that the period in which they inhabited these regions, was that immediately preceding the formation of this gravel, and that they perished by the same waters which produced it. M. Cuvier has moreover ascertained, that the fossil elephant, rhinoceros, hippopotamus, and hyæna, belong to species now unknown; and as there is no evidence that they have at any time, subsequent to the formation of the diluvium, existed in these regions, we may conclude that the period, at which the bones of these extinct species were introduced into the cave at Kirkdale, was antediluvian. Had these species ever re-established themselves in the northern portions of the world since the deluge, it is probable their remains would have been found, like those of the ox, horse, deer, hog, &c. preserved in the post-diluvian accumulations of gravel, sand, silt, mud, and peat, which are referable to causes still in operation, and which, by careful examination of their relations to the adjacent country, can be readily distinguished from those which are of diluvian origin.

The teeth and fragments of bones above described, seem to have lain a long time scattered irregularly over the bottom of the den, and to have been continually accumulating until the introduction of the sediment in which they are now imbedded, and to the protection of which they owe that high state of

preservation they possess. Those that lay long uncovered at the bottom of the den, have undergone a decay proportionate to the time of their exposure; others that have lain only a short time before the introduction of the diluvian mud, have been preserved by it almost from even incipient decomposition.

Thus the phenomena of this cave seem referable to a period in which the world was inhabited by land animals, bearing a general resemblance to those now existing, before the last inundation of the earth; but so completely has the violence of that tremendous convulsion destroyed and remodelled the form of its antediluvian surface, that it is only in caverns that have been protected from its ravages, that we may hope to find undisturbed evidence of events in the period immediately preceding it. The bones already described, and the stalagmite formed before the introduction of the diluvial mud, are what I consider to be the products of the period in question. It was indeed probable, before the discovery of this cave, from the abundance in which the remains of similar species occur in superficial gravel beds, which cannot be referred to any other than a diluvial origin, that such animals were the antediluvian inhabitants of this country; but the proof was imperfect, as it has been said they might have been drifted or floated hither by the waters, from warmer latitudes: but the facts developed in this charnel house of the antediluvian forests of Yorkshire, show that there was a long succession of years in which these animals had been the prey of the hyænas, which like themselves at that time, must have inhabited these regions of the earth; and it is in the diluvial wreck occurring in such latitudes, that similar bones have been

found buried, in the state of grave bones, over great part of northern Europe, as well as North America and Siberia. The catastrophe producing this gravel, appears to have been the last event that has operated generally to modify the surface of the earth, and the few local and partial changes that have succeeded it, such as the formation of deltas, terraces, tufa, torrent-gravel and peat-bogs, all conspire to show, that the period of their commencement was subsequent to that at which the diluvium was formed.*

* It was stated in describing the locality of the cave at Kirkdale, and on comparing it with the fact of its containing the remains of large and small aquatic animals, that there was probably a lake in this part of the country at the period when they inhabited it; and this hypothesis is rendered probable by the form and disposition of the hills that still encircle the Vale of Pickering. (See Map, Plate XV.)

Inclosed on the south, the west, north-west, and north, by the lofty ranges of the Wolds, the Howardian hills, the Hambleton hills, and Eastern Moorlands, the waters of this vale must either run eastward to Filey Bay, or inland towards York; and such is the superior elevation of the strata along the coast, that the sources of the Derwent, rising almost close to the sea, near Scarborough and Filey, are forced to run west and southward fifty miles inland away from the sea, till falling into the Ouse, they finally reach it by turning again eastward through the Humber. The only outlet by which this drainage is accomplished, is the gorge at New Malton; and though it is not possible to ascertain what was the precise extent of this antediluvian lake, or how much of the low districts, now constituting the Vale of Pickering, may have been excavated by the same diluvian waters that produced the gorge; it is obvious, that without the existence of this gorge, much of the district within it would be laid under water; and it is equally obvious, that the gorge is referable to the agency of diluvian denudation, the ravages of which have not, perhaps, left a single portion of the antediluvian surface of the whole earth, which is not torn and re-modelled, so as to have lost all traces of the exact features it bore antecedently to the operations of the deluge.

It is probable, that inland lakes were much more numerous than they are at present, before the excavation of the many gorges by which our modern rivers make their escape; and this is consistent with the frequent occurrence of the remains of the hippopotamus in the diluvian gravel of England, and of various parts of Europe.

It is in the highest degree curious to observe, that four of the genera of animals whose bones are thus widely diffused over the temperate, and even polar regions of the northern hemisphere, should at present exist only in tropical climates, and chiefly south of the equator; and that the only country in which the elephant, rhinoceros, hippopotamus and hyæna are now associated, is Southern Africa. In the immediate neighbourhood of the Cape they all live and die together, as they formerly did in Britain; whilst the hippopotamus is now confined exclusively to Africa, and the elephant, rhinoceros and hyæna are also diffused widely over the continent of Asia.

Such are the principal facts I observed in the interior of the cave at Kirkdale, and such the leading conclusions that seem to arise from them; and I cannot sufficiently lament that I was not present at its first opening, to witness the exact state in which it appeared, before any part of the surface of the mud had been disturbed.

From the description given of the state of the bones, and of the mud and stalactite that accompany them, we may extract the following detailed history of the operations that have successively been going on within the cave.

1st. There appears to have been a period (and if we may form an estimate from the small quantity of stalagmite now found on the actual floor of the cave, a very short one,) during which this aperture in the rock existed, but was not

It is not unlikely that, in this antediluvian period, England was connected with the Continent, and that the excavation of the shallow channel of the Straits of Dover, and of a considerable portion of that part of the German ocean which lies between the east coast of England and the mouths of the Elbe and Rhine, may have been the effect of diluvial denudation. The average depth of all this tract of water is said to be less than thirty fathoms.

tenanted by the hyænas. The removal of the mud, which now entirely covers the floor, would be necessary to ascertain the exact quantity of stalagmite referable to this period; but it cannot be very great, and can only be expected to exist where there is much stalactite also upon the roof and sides.

The 2d period was that during which the cave was inhabited by the hyænas, and the stalactite and stalagmite were still forming. The constant passage of the hyænas in so low a cave, would much interrupt this formation; as they would strike off the former from the roof and sides by their constant ingress and egress; and accordingly in some specimens of the breccia, we find mixt with the bones, fragments of stalactite, that seem to have been thus knocked off from the roof and sides of the cave, whilst it was inhabited by hyænas before the introduction of the mud; I have one example of a hollow stalactitic tube that lay in an horizontal position in the midst of, and parallel to, some long splinters of bone and the unbroken ulna of a rat: all these are united by stalagmite; and it is impossible that this stalactitic pipe could have been formed in any other than a vertical position, hanging from the roof or sides. In other specimens of the breccia, I have split fragments of the teeth of deer and hyæna; and in almost every portion I have seen, either of this breccia or of the antediluvian stalagmite, there are teeth of the water rat. Mr. Gibson possesses a mass exceeding a foot in diameter, composed of fragments of many large bones, mixed with some teeth of rhinoceros and several of the larger animals, and also of rats, all adhering firmly together in a matrix of stalagmite. It did not occur to me, whilst on the spot, to examine whether the bottom of the

cave is any where polished (like the tiger's den before alluded to), in those parts which must have been the constant gangway of the hyænas; but the universal cover of mud by which it is buried, renders it necessary that this should be removed, in order to the observation I suggest. During the formation of this stalactitic matter, no mud appears to have been introduced; and had there been any in the cave at the time whilst the osseous breccia was forming, it would either have excluded all access of the stalagmite to the bones, or have been mixed and entangled with it in very large proportions, forming a spongy mass, such as it does at the root of the stalagmites that lie on its surface.

The 3rd period is that at which the mud was introduced and the animals extirpated, viz. the period of the deluge. I have already stated that the animal remains are found principally in the lower regions of this sediment of mud, which appears to have been introduced in a fluid state, so as to envelope the bony fragments then lying on the bottom of the cave: and the power of water to introduce such sediments is shown by the state of Wokey Hole, and similar caverns in the Mendip Hills, and Derbyshire, which are subject to be filled with water occasionally by heavy land floods. The effect of these floods being to leave on the floor, a sediment of mud precisely similar to that which covers the bones and osseous breccia in the cave of Kirkdale. I have also mentioned that there is no alternation of this mud with beds of bone or of stalagmite, such as would have occurred had it been produced by land floods often repeated; once, and once only it appears to have been introduced; and we may probably consider its vehicle to have been the turbid

waters of the same inundation that produced the diluvial gravel: these would enter and fill the cave, and there becoming quiescent, would deposit the mud suspended in them (as we see daily silt and warp deposited in quiet spots by waters of muddy rivers) along the whole bottom of the den, where it has remained undisturbed ever since. We cannot refer this mud to a land flood, or a succession of land floods, partly for the reasons before stated, and partly from the general dryness of the cave; had it been liable to be filled with muddy water, it would have been so at the time I visited it in December, 1821, at the end of one of the most rainy seasons ever remembered; but even then there were not the slightest symptoms of any such occurrence, and a few scanty droppings from the roof were the only traces of water within the area of the cavern.

The 4th period is that during which the stalagmite was deposited which invests the upper surface of the mud. The quantity of this stalagmite appears to be much greater than that formed in the two periods during, and before which, the cave was tenanted by hyænas. In the whole of this 4th period no creature appears to have entered the cave, with the exception possibly of mice, weasels, rabbits, and foxes, until it was opened last summer, and no other process of any kind appears to have been going on in it except the formation of stalactitic infiltrations; the stratum of diluvial sediment marks the point of time at which the latter state of things began and the former ceased. As there is no mud at all on the top or sides of the cave, we have no mark to distinguish the relative quantities of stalactite formed on these parts during the periods we have been speaking of: should it however contain in any

part a fragment of bone or tooth of any of the extinct animals, it will follow that this part was antediluvial. A farther argument may be drawn from the limited quantity of post-diluvian stalactite, as well as from the undecayed condition of the bones, to show that the time elapsed since the introduction of the diluvian mud, has not been one of excessive length.

The arguments arising from the detail of facts we have been describing, are applicable to the illustration of analogous phenomena, where the evidence of their history is less complete. In our own country there are five other instances of bones similarly deposited in caverns, the origin of some of which, though not before satisfactorily made out, becomes evident as a corollary from the proofs afforded by the cave at Kirkdale: these are in Glamorganshire, Somersetshire, Derbyshire, and Devonshire.

1. The first is in the parish of Nicholaston, on the coast of Glamorganshire, at a spot called Crawley Rocks, in Oxwich Bay, about twelve miles S.W. of Swansea; it was discovered in the year 1798, in a quarry of lime-stone, on the property of T. M. TALBOT, Esq. of Penrice Castle, and no account of it has, I believe, been ever published; some of the bones however are preserved in the collection of Miss TALBOT, at Penrice: they are as follows:

Elephant——Three portions of large molar teeth.
Rhinoceros—Right and left ossa humeri.
One atlas bone.
Two molar teeth of upper jaw.
Ox————First phalangal bone of left fore foot.
Stag————Lower extremity of the horn.

Stag————Three molar teeth.

One first phalangal bone, right leg.

Hyæna————Two canine teeth, much worn.

These bones were found in a cavity of mountain lime-stone, which was accidentally intersected, like the cave at Kirkdale, in working a quarry: they have a slight ochreous incrustation, and a little earthy matter adhering to them; but are not in the least degree rolled; and the condyles of the two humeri of the rhinoceros, belonging to different individuals, have in each case been entirely broken off, as if by gnawing. The two canine teeth of hyæna (worn down to the stumps), that were found in the same cave with them, afford ground for probable conjecture as to the means by which those bones were thus broken, as well as introduced to this cave in Glamorganshire.*

2. The next case I shall mention is that of teeth and bones of elephants and other animals discovered in the Mendip Hills in cavities of mountain lime-stone, which were lined, and nearly filled with ochreous clay. These are preserved in the collection of the Rev. Mr. Catcott, in the City Library at Bristol. The following account of them is extracted by my friend the Rev. W. D. Conybeare, from Mr. Catcott's MS. notes; he has added also a few explanatory observations.

"The ochre pits were worked about the middle of the last century, near the summit of the Mendip Hills, on the S. of

* On comparing one of these humeri of the rhinoceros with a similar bone from the cave at Kirkdale, I found in each case both extremities of the bone broken or gnawed off exactly to the same point, i. e. just so far as was sufficient to extract the marrow and take off the most spongy portions of the extremities, whilst the parts remaining were only the hardest and most compact cylindrical portions of the centre of the bones in question.

the village of Hutton, near Banwell, at an elevation of from three hundred to four hundred feet above the level of the sea: they are now abandoned.

"The ochre was pursued through fissures in the mountain lime-stone, occasionally expanding into larger cavernous chambers, their range being in a steep descent, and almost perpendicular. Thus, in opening the pits, the workmen, after removing eighteen inches of vegetable mould, and four feet of rubbly ochre, came to a fissure in the lime-stone rock, about eighteen inches broad, and four feet long. This was filled with good ochre, but as yet no bones were discovered; it continued to the depth of eight yards, and then opened into a cavern about twenty feet square, and four high; the floor of this cave consisted of good ochre, strewed on the surface of which were multitudes of white bones, which were also found dispersed through the interior of the ochreous mass. In the centre of this chamber, a large stalactite depended from the roof; and beneath, a similar mass rose from the floor, almost touching it: in one of the side walls was an opening about three feet square, which conducted through a passage eighteen yards in length, to a second cavern, ten yards in length, and five in breadth, both the passage and cavern being filled with ochre and bones; another passage, about six feet square, branched off laterally from this chamber about four yards below its entrance; this continued nearly on the same level for eighteen yards; it was filled with rubbly ochre, fragments of lime-stone rounded by attrition, and lead ore confusedly mixed together; many large bones occurring in the mass; among which four magnificent teeth of an elephant (the whole number belonging to a single skull) were found; another shaft was sunk from the surface perpendicularly into

his branch, and appears to have followed the course of a fissure, since it is said that all the way nothing appeared but rubble, large stones, ochre, and bones: in the second chamber, immediately beyond the entrance of the branch just described, there appeared a large deep opening, tending perpendicularly downwards, filled with the same congeries of rubble, ochre, bones, &c.; this was cleared to the depth of five yards; this point, being the deepest part of the workings, was estimated at about thirty-six yards beneath the surface of the hill; a few yards to the west of this another similar hole occurred, in which was found a large head, which we shall have occasion presently to notice."

The bones from this cavern, preserved in Mr. CATCOTT's cabinet in the Bristol library, are the teeth and fragments of some bones of the elephant; and similar remains of horses, oxen, and two species of stag, besides the skeleton, nearly complete, of a fox. There are also molar teeth of the hog, and a large tusk of the upper jaw; (see Pl. XXV. fig. 30, 31, 32, 33.) This tusk probably belonged to the head mentioned in his MS. as having been found in the pit above described, and of which the following particulars are specified:—"The head was stated by the workmen to have been about three or four feet long, fourteen inches broad at the top, or head part, and three inches at the snout. It had all the teeth perfect, and four tusks, the larger tusks about four inches long out of the head, and the lesser about three inches."* The tusk now

* The head here described, is evidently that of a hog; the account of its length being exaggerated by the workmen, from whose report alone Mr. CATCOTT gives the measure of it. The head itself was lost or destroyed before he had seen it.

preserved is about three inches long, its enamel is fine, it is longitudinally striated, and on one side of the apex truncated and worn flat by use.

On the summit of Sandford Hill, on the east of Hutton, bones of the elephant were also, according to Mr. CATCOTT's MSS., discovered four fathoms deep among loose rubble. Some farther detail of the bones found in the cave at Hutton are given as a note in Mr. CATCOTT's Treatise on the Deluge (page 361, 1st. edition), in which he specifies six molar teeth of the elephant, one of them lying in the jaw, part of a tusk, part of a head, four thigh bones, three ribs, with a multitude of lesser bones, belonging probably to the same animal. "Besides these (he adds), we picked up part of a large deer's horn very flat, and the slough of a horn (or the spongy porous substance that occupies the inside of the horns of oxen), of an extraordinary size, together with a great variety of teeth and small bones belonging to different species of land animals. The bones and teeth were extremely well preserved, all retaining their native whiteness, and, as they projected from the sides and top of the cavity, exhibited an appearance not unlike the inside of a charnel-house."

It appears to me most probable, from the description given of these bones and horns, that they were not all dragged in by beasts of prey, but some of them, at least, drifted in by water, and the presence of pebbles seems to add credibility to this conjecture.

3. Another case of fossil fragments of bone has been discovered by Mr. MILLER, of Bristol, in a cavity of mountain lime-stone, near Clifton, by the turnpike gate on Derdham

Down: these are not rolled, but have evidently been fractured by violence: they are partially incrusted with stalactitic matter, and the broken surfaces have also an external coating of thin ochreous stalactite, showing the fracture to have been ancient; one specimen, the property of Mr. Miller, displays the curious circumstance of a fossil joint of the horse; it is the tarsus joint, in which the astragalus retains its natural position between the tibia and os calcis; these are held together by a stalactitic cement, and were probably left in this position by some beast of prey that had gnawed off the deficient portions of the tibia and os calcis.

4. A fourth case is that of some bones and molar teeth of the elephant, found in another cavity of mountain lime-stone at Balleye, near Wirksworth, in Derbyshire, in the year 1668; one of these teeth is now in the collection of Mr. White Watson, of Bakewell. There is, I believe, no detailed account of the circumstances under which these remains were found, farther than that the cavity was intersected in working a lead mine; they might possibly have been introduced in the same manner as those at Kirkdale and Crawley Rocks.

5. The fifth and last example which I am acquainted with, is that described by Sir Everard Home and J. Whidby, Esq. in the Philosophical Transactions for 1817, as discovered at Oreston, near Plymouth, by Mr. Whidby, in removing the entire mass of a hill of transition lime-stone for the construction of the Breakwater. This lime-stone is full of caverns and fissures, such as may be seen at Stonehouse and elsewhere along the edge of the cliffs; that in which the bones were found was fifteen feet wide, twelve high, and

forty-five long, and about four feet above high water mark; it was filled with solid clay (probably diluvian mud) in which the teeth and bones were imbedded, and was intersected in blasting away the body of the rock to make the Breakwater. The state of the teeth and bones was precisely the same with that of those found at Crawley rocks, they were much broken, but not in the slightest degree rounded by attrition, and Sir EVERARD HOME has ascertained them to belong exclusively to a species of rhinoceros. A similar discovery of teeth and bones was made in 1820, in a smaller cavern, distant one hundred and twenty yards from the former, being one foot high, eighteen wide and twenty long, and eight feet above the high water mark; a description of its contents is given in the Philosophical Transactions for 1821, by the same Gentlemen. It contained no stalactite, which abounds in many of the adjacent caverns. Sir EVERARD HOME describes these teeth and bones as belonging to the rhinoceros, deer, and a species of bear.

Mr. WHIDBY is of opinion, that neither of these caverns had the appearance of ever having had any opening to the surface, or communication with it whatever; an opinion in which I can by no means acquiesce; though I think it probable that the openings had, as at Kirkdale, been long ago filled up with rubbish, mud, stalactite, or fragments of rock re-united, as sometimes happens, into a breccia as solid as the original rock, and overgrown with grass. It is now too late to appeal to the evidence of facts, as the rock in which the cave existed is entirely removed; but the circumstances of similar caverns that have communication with the surface, either open or concealed, both in this neighbourhood, and in compact lime-stone rocks of all ages and formations, and in all

countries, added to the identity of species and undecayed state of the animal remains which they contain, render the argument from analogy perfect, to show that the bones at Oreston are not coeval, and have only an accidental connection with the rock in the cavities of which they were found.

It by no means follows, from the certainty of the bones having been dragged in by beasts of prey to the small cavern at Kirkdale, that those of similar animals must have been introduced in all other cases in the same manner; for, as these animals were the antediluvian inhabitants of the countries in which the caves occur, it is possible, that some may have retired into them to die, others have fallen into the fissures by accident and there perished, and others have been washed in by the diluvial waters. By some one or more of these three latter hypotheses, we may explain those cases in which the bones are few in number and unbroken, the caverns large and the fissures extending upwards to the surface; but where they bear marks of having been lacerated by beasts of prey, and where the cavern is small, and the number of bones and teeth so great, and so disproportionate to each other as in the cave at Kirkdale, the only adequate explanation is, that they were collected by the agency of wild beasts. We shall show hereafter, that in the case of the German caves, where the quantity of bones is greater than could have been supplied by ten times the number of carcases which the caves, if crammed to the full, could ever have contained, they were the bones of bears that lived and died in them during successive generations.

We may now proceed to consider how far the circum-

stances of the caves we have been examining in England, appear consistent with those of analogous caverns in other parts of the world. The history of the diluvian gravel of the Continent, and of the animal remains contained in it, appears altogether identical with that of our own; and with respect to the bones that occur in caverns, the chief difference seems to be, that on the Continent some of the caves have their mouths open, and have been inhabited in the *post-diluvial* period by animals of now existing species. Thus at Gailenreuth the great extinct bear (Ursus spelæus) occurs, together with the Yorkshire species of extinct hyæna, in a cave, the mouth of which has no appearance of having ever been closed, and which at this moment would, probably, have been tenanted by wild beasts, had not the progress of human population extirpated them from that part of Germany.

For a description of the cavern at Gailenreuth, (which I visited in 1816) of which, in Plate XXVI. I have given a sectional representation, I must refer to the work of ROSENMULLER, published at Weimar in 1804, in folio, with engravings of nearly all the bones composing the skeleton of the extinct bear, the size of which approached nearly to that of a horse; and for a description of the caves at Blankenburg, to an account by ESPER and LEIBNITZ, published at Brunswick.

M. ROSENMULLER says, he has never seen the remains of the elephant and rhinoceros in the same cavern with those of bears; and that he has found the bones of wolves, foxes, horses, mules, oxen, sheep, stags, roebucks, badgers, dogs, and men;* and that the number of all these is in no propor-

* M. ESPER has found in one of the caverns containing bears' bones, fragments of urns, which from their form were probably made at least 800 years ago.

tion to that of the bears. The bones of all kinds occur in scattered fragments. One entire skeleton only of the Ursus spelæus is said to have been found by BRUCKMANN, in a cave in the Carpathians, and to have been sent to Dresden. He adds, that the different state of these bones shows that they were introduced at different periods, and that those of all the animals last enumerated, including man, are in much higher preservation than those of the bears and hyænas.

Thus it appears that the bones which are in most perfect preservation, and belong to existing species, have been introduced during the *post-diluvian* period; whilst the extinct bears and hyæna are referable to the antediluvian state of the earth. In corroboration of this, I found in 1820, in the collection of the Monastery of Kremsminster, near Steyer, in Upper Austria, skulls and bones of the Ursus spelæus in consolidated beds of diluvial gravel, forming a pudding-stone, and dug for building near the monastery; from which it appears that this species of bear lived in the period immediately preceding the formation of that diluvium; and the same thing has been already shown of the extinct hyæna in the gravel of France and Germany.

M. ROSENMULLER states that in all the caverns he has examined, the bones are disposed nearly after the same manner; sometimes scattered separately, and sometimes accumulated in beds and heaps of many feet in thickness; they are found every where from the entrance to the deepest and most secret recesses; never in entire skeletons, but single bones mixed confusedly from all parts of the body, and animals of all ages. The skulls are generally in the lowest part of the beds of bone, having from their form and weight sunk

or rolled downwards, as the longer and lighter bones were moved and disturbed continually by the living animals passing over them; the lower jaws are rarely found in contact with, or near to the upper ones, as would follow from the fact last mentioned.* They are often buried in a brown argillaceous or marly earth, as in the cases of Gailenreuth, Zahnloch, and in the Hartz, which earth, from an analysis by M. FRISCHMAN, seems to contain a large proportion of animal matter derived from the decay of the fleshy parts of the bears.

In the caves of Gailenreuth and Mockas, a large proportion of the bones is invested with stalactite. Even entire beds, and heaps of them many feet thick, are sometimes cemented together by it, so as to form a compact breccia. Occasionally they adhere by stalactite to the sides of the cavern, but are never found in the substance of the rock itself. At Sharzfelden, and in the Carpathians, they have been found enveloped with agaric mineral (lac lunæ); they have undergone no alteration of form, but the larger bones are generally separated from their epiphyses. Their usual colour is yellowish white, but brown where they have lain in dark coloured earth, as at Lichtenstein. At Mockas their degree of decay is by far the greatest. Even the enamel of the teeth is far gone, and the bones are perfectly white, having lost all their animal

* At Kirkdale, not one skull, and few, if any, of the larger bones are found entire; for these had all been broken up by the hyænas to extract the brains and marrow; and in their strong and worn out teeth we see the instruments by which they were thus destroyed. The bears, on the other hand, not being exclusively carnivorous, nor having teeth fitted for the cracking of large bones, have left untouched the osseous remains of their own species.

gluten, and acquired the softness and spongy appearance, as well as colour, of calcined bones; still their form is perfect, and substance inflexible, and when struck, they ring like metallic bodies falling to the ground. These retain simply their phosphate of lime. In other caverns they are usually less decayed, but they sometimes exfoliate and crack on exposure to air, and the teeth, particularly, are apt to split and fall to pieces, as are also those at Kirkdale.*

M. ROSENMULLER is decidedly of opinion with M. CUVIER, that the bears' bones are the remains of animals which lived and died through successive generations in the caves in which we find them; nay, even that they were also born in the same caves. In proof of which he has found some bones of a bear, that must have died immediately after birth, and other bones of individuals that must have died young. This is analogous to the case of numerous teeth of young hyænas with fangs not formed; and the jaws of two that had not shed their first teeth, which I found at Kirkdale.

Most of the arguments which I have used to show that the bones in Yorkshire cannot have been accumulated by the action of one, or of a succession of floods, apply with equal force to the cave at Gailenreuth, and it is unnecessary to repeat them.

The above description of the cave at Gailenreuth, extracted from ROSENMULLER, and confirmed by my own observations

* It is a curious fact, that of the numerous caves in the calcareous hills near Muggendorf, that flank the valley of the Weisent-stream, those on the north chain contain not a fragment of the bones of the Ursus spelæus, while those on the south side are full of them. This may probably be explained by supposing the mouths of the former to have been closed in the antediluvian period, and afterwards laid open by denudation.

on the spot, may be taken as an example of the state of the other caves on the Continent, of which it is superfluous here to say any thing farther, than to subjoin a list given by M. CUVIER of the most important of them, and to refer to the fourth Volume of his *Animaux fossiles*, for farther details taken from the authors by whom these caves have been described.

The caves alluded to are as follows:

1. That of Bauman, in the county of Blankenberg, in Brunswick, on the east border of the Hartz forest, and described by LEIBNITZ.

2. That of Sharzfels, in Hanover, in the south border of the Hartz, described by LEIBNITZ, DELUC, and BRUCKMANN.

BEHRENS, in his Hercynia Curiosa, speaks of several more in the neighbourhood of the Hartz; from most of these the bones were collected during a long course of years, and sold for their imaginary medicinal virtues under the name of Licorne.

3. The caves that next attracted attention were those of the Carpathians, and the bones found in them were at first known by the name of dragons' bones, and have been described by HAYNE and BRUCKMANN.

4. But the most richly furnished are the caves of Franconia, described by ESPER and ROSENMULLER, near the sources of the Mayn, in the vicinity of Bamberg and Bayreuth, at the villages of Gailenreuth, Mockas, Rabenstein, Kirch-a-horn, Zahnloch, Zewig, and Hohen Mirchfeld.

5. A fifth locality occurs at Glücksbrun, near Meinungen, on the south border of the Thuringerwald.

6. And a sixth in Westphalia, at Kluterhoehle and Sund-

wich, in the country of Mark. M. CUVIER states, that the bones found in these caverns are identical over an extent of more than 200 leagues; that three-fourths of the whole belong to two species of bear, both extinct; the Ursus spelæus and Ursus arctoideus, and two-thirds of the remainder to extinct hyænas. A very few to a species of the cat family, being neither a lion, tiger, panther, or leopard, but most resembling the jaguar, or spotted panther of South America. There is also a wolf or dog (not distinguishable from a recent species), a fox and polecat. He adds that, in the caves thus occupied, there occur no remains of the elephant, rhinoceros, horse, ox, tapir, or any of the ruminantia or rodentia. In this respect they differ materially from that of Yorkshire; but such variation is consistent with the different habits of bears and hyænas, arising from the different structure of their teeth and general organization; from which it follows, that bears prefer vegetable food to that of animals, and, when driven to the latter, prefer sucking the blood to eating the flesh, whilst hyænas are beyond all other beasts addicted to gnawing bones.

From this circumstance it is rendered probable, that in the caves inhabited chiefly by bears, the bones of other animals should be extremely rare. But unless there be an error in the statement of M. DELUC (Lettres, vol. iv. p. 588), that a tooth found in the cave at Scharzfels was ascertained by M. HOLLMAN to be that of a rhinoceros; and of ESPER, that large cervical vertebræ of an elephant were found by M. FRISCHMAN in the cave of Schneiderloch; it follows, that these two animals occur, though very rarely, in the caves of Germany, and they may have been introduced by the few hyænas that

occasionally inhabited them; that they lived in the neighbourhood of these caves, in the period immediately preceding the formation of the diluvium, is probable, from the occurrence in it of the bones of the elephant and rhinoceros near the caves of Scharzfels and Alterstein, mentioned by BLUMENBACH. (Archaeologia Telluris, p. 15.)

The fact mentioned by M. CUVIER, of the same hyæna being common to the caves and gravel of France and Germany, and that ascertained by myself, of the Ursus spelæus occurring in the gravel of Upper Austria, proves both these extinct species to have been the antediluvian contemporaries of the extinct elephant and rhinoceros; there is therefore no anachronism in finding the remains of the two latter in a den that was occasionally inhabited by such hyænas and bears.

With respect to the analogies of the diluvian sediment and the stalactite in Germany and Yorkshire, in the case of the open caves that have been disturbed and ransacked for centuries, it is hopeless to expect evidence of what was the precise state of these deposits in each individual cavern at the time it was first entered. Still there is information respecting some that have been recently discovered, which is to our purpose. It is stated, that a sediment of this kind was found on the sides and floor of the cave at Glucksbrun, near Meinungen, when it was newly opened in cutting a road in 1799, and that in all the other caverns also there is mud, but no rounded pebbles. M. DELUC, in describing the matrix in which the bones are lodged in the cave at Scharzfels, says, "le fait est donc simplement, que le sol de ces cavernes est d'une terre calcaire," "qu'en creusant cette couche molle, on en tire quantité de fragmens d'os; et qu'il s'y trouve aussi des concrétions pier-

reuses qui renferment des os." DELUC, Lettres, vol. iv. p. 590. These concretions with bones appear analogous to the stalagmitic concretions at Kirkdale, and the soft calcareous earth by which they are covered, resembles its stratum of mud. Again, the resemblance holds also in the existence both of bones and soft mud in the smallest recesses of the caverns. He says, p. 589, "Il faut en quelques endroits se trainer sur le ventre, par dessous la pierre dure pour continuer a y creuser." This is an exact description of the state of the extremities of the cave at Kirkdale at the present moment.

LEIBNITZ, in his description of this same cavern, has the following words to the same purpose, "Limo nigricante vel fusco infectum est solum." LEIBNITZ, Protogaea, p. 65.

ESPER thus describes the state of the floor near the entrance of one of the largest caverns at Gailenreuth. "Dans toute la contrée le terrain est marneux, mêlé avec du limon, et tire sur le jaune, mais ici on trouve une terre moins limoneuse dans une profondeur considérable. Je ne prétends pas encore la prendre absolument pour une terre animale telle qu'est sans contredit la terre qui se trouve plus bas, mais probablement elle doit y être rapportée, p. 9. This again is consistent with the circumstances of the cave at Kirkdale, the mud, thus dubiously spoken of, being probably of diluvial origin, and reposing on, and being mixed with, the animal earth that had been formed before its introduction. The absence of black animal earth at Kirkdale, results from the fact of the flesh, and great part even of the bones of the animals introduced to it, having been eaten by the hyænas.

The identity of time and circumstances which I am endeavouring to establish between the German and English

caverns, does not, however, depend so much on comparisons between the stalactitic matter and earthy sediments which they contain, as on the agreement in species of the animals entombed in them, viz. in the agreement of the animals of the English caves, with those of the diluvian gravel of the greater part of Europe; and, in the case of the German caves, on the identity of the extinct bear with that of the diluvian gravel of Upper Austria, and the extinct hyæna with that of the gravel at Canstadt, in the valley of the Necker; and at Eichstadt, in Bavaria; to these may be added the extinct rhinoceros, elephant, and hippopotamus, which are common to gravel beds as well as caves. And hence it follows, that the period at which all these caverns were inhabited by the animals in question, was antecedent to the formation of that deposit of gravel, which it seems to me impossible to ascribe to any other origin than a transient deluge, affecting universally, simultaneously, and at no very distant period, the entire surface of our planet.

The bones found in these caverns are considered by M. CUVIER, to be of older date than those of the osseous breccia, which, at Gibraltar and various places along the coast of the Mediterranean and Adriatic, occur in vertical fissures of limestone. This breccia contains fragments of bones and teeth of various ruminating and gnawing animals; that is, of ox, deer, antelope, sheep, rabbits, rats, mice; also of the horse and ass, of snakes and birds, mixed with land shells, and angular fragments of the adjacent rock; all united into a solid breccia by ochreous stalactite. The greater number of these animals agree with species that now exist, and are supposed by M. CUVIER to have fallen into the fissures in

the period succeeding the last retreat of the waters. I do not see why some of them may not also have fallen in during that earlier period in which the bears occupied the caves of Germany, and the hyænas that in Yorkshire; for some of the animals found at Kirkdale seem to agree in species with those that occur in the fissures; but as they are at the same time not distinguishable from existing species, the argument arising from this resemblance is imperfect. The discovery of the extinct elephant, rhinoceros, hippopotamus, bear, and hyæna in this breccia, should it ever be made, would be decisive of the question.

For an account of the bones accumulated in these fissures, I must again refer to the works of M. Cuvier, which contain more sound and clear philosophical reasoning on the early state of habitation on our planet, and a more valuable collection of authentic facts relating to the history of its fossil animals of the higher orders, than can be found in all the books that have ever yet been written on the subject.

## APPENDIX.

It was mentioned, when speaking of Gailenreuth, that human remains had been discovered there in the same cave with the bones of antediluvian animals, but that they are of comparatively low antiquity.

Three analogous cases have been noticed in this country in cavities of mountain lime-stone, at Burringdon, in Somersetshire, and in Glamorganshire and Caermarthenshire; and these also are attended by circumstances which indicate them to be of post-diluvian origin.

1. The discovery of human bones incrusted with stalactite, in a cave of mountain lime-stone at Burringdon, in the

Mendip-hills, is explained, by this cave having either been used as a place of sepulture in early times, or been resorted to for refuge by wretches that perished in it, when the country was suffering under one of the numerous military operations which, in different periods of our early history, have been conducted in that quarter. The mouth of this cave was nearly closed by stalactite, and many of the bones were incrusted with it. In the instance of a skull, it had covered the inside as well as the outside of the bone; and I have a fragment from the inside, which bears in relief casts of the channel of the veins along the interior of the skull. The state of these bones affords indications of very high antiquity; but there is no reason for not considering them post-diluvian. Mr. SKINNER, on examination of this cave, found the bones disposed chiefly in a recess on one side, as in a sepulchral catacomb; and in the same neighbourhood, at Wellow, there is a large artificial catacomb of high antiquity, covered by a barrow, and constructed after the manner of that at New Grange, near Slane, in the county of Meath, of stones successively overlapping each other till they meet in the roof. In this were found the remains of many human bodies. A description of it may be seen in the Archæologia for 1820.

2. Mr. DILLWYN has observed two analogous cases in the mountain lime-stone of South Wales; one of these was discovered, in 1805, near Swansea, in a quarry of lime-stone at the Mumbles, where the workmen cut across a wedge-shaped fissure, diminishing downwards, and filled with loose rubbish, composed of fragments of the adjacent lime-stone, mixed with mould. In this loose breccia lay, confusedly, a large number of human bones, that appear to be the remains of bodies thrown in after a battle, with no indications of regular

burial; they were about 30 feet below the present upper surface of the lime-stone rock.

3. The other case occurred, in 1810, at Llandebie, in Caermarthenshire, where a square cave was suddenly broken into, in working a quarry of solid mountain lime-stone on the north border of the great coal basin. In this cave lay about a dozen human skeletons in two rows at right angles to each other. The passage leading to this cave had been entirely closed up with stones for the purpose of concealment, and its mouth was completely grown over with grass.

It is obvious, that in neither of these cases, are the bones referable to so high an era as those of the wild beasts that occur in the caves at Kirkdale, and elsewhere.

P.S. As this paper was going to the press, I have been gratified to hear that my conjecture, as to the abundance of such caverns as that at Kirkdale, has been verified by the discovery of another cave (containing chambers lined with stalactite, and having on its bottom mud, and bones imbedded in the mud), in a quarry close to the town of Kirby Moorside, on the property of C. Duncombe, Esq., who has judiciously taken every precaution to secure it from injury, till some qualified person shall be present to observe, and record the undisturbed appearance presented by its interior. Should it be in my power, as I hope it may, to assist at its farther opening, I shall communicate the result to the Royal Society.

It is recollected also, that about 20 years ago, another cavity, containing bones, was discovered on the north of Kirby Moorside, but none of them have been preserved.

Though it is probable, as I have stated, that such caverns are not uncommon, we shall cease to wonder that they are

so rarely brought to light, when we consider the number of accidental circumstances that must concur to lead to such an event. 1st, The existence of caverns is an accidental circumstance in the interior of the rock, of which the external surface affords no indication, when the mouth is filled with rubbish and overgrown with grass. 2d, The presence of bones is another accidental circumstance, though probably not an uncommon one in the case of those caves, the mouths of which were accessible to the wild beasts that inhabited this country in the period immediately preceding the deluge. 3d, A farther requisite is, the intersection of one of these caves in which there happen to be bones, by a third accident, viz. the working of a stone quarry by workmen who have sufficient curiosity or intelligence to notice and speak of what they find, and this to persons who may be willing or able to appreciate, and give publicity to the discovery. The necessary concurrence of all these contingencies renders it probable, that however great may be the number of subterraneous caverns, in an inland country, very few of them will ever be discovered, or if discovered, be duly appreciated. Those I have mentioned in Devon, Somerset, Derby and Glamorganshire, were all laid open by the accidental operations of a quarry or mine.

May 24. 1822. I have this day received the entire lower jaw of an hyæna from Lawford, near Rugby, in Warwickshire. It was found by ANDREW BLOXAM, Esq. in the same diluvial clay and gravel with the bones of elephant and rhinoceros. This is the first instance of the remains of hyæna being noticed in the diluvium of England. The animal must have perished by the same catastrophe which extirpated the hyænas, and closed the den at Kirkdale, and which swept together the remains of elephant, rhinoceros and hyæna in the diluvian gravel of the Continent. The support which this recent discovery gives to my arguments on the cave in Yorkshire, is too obvious to require pointing out.

## EXPLANATION OF THE PLATES.

All the Drawings are of the natural size, unless where it is expressed to the contrary.

### Plate XV.

Map of the country adjacent to the cave at Kirkdale, showing the entire drainage of the vale of Pickering to be effected through the gorge at Malton, the stoppage of which would at once convert it into an inland lake.

### Plate XVI.

Fig. 1. View of the mouth of the cave at Kirkdale, in the face of a quarry, near the brow of a low hill.

Fig. 2. Section of the cave before the mud had been disturbed.

A. Stratum of mud covering the floor of the cave to the depth of one foot, and concealing the bones.

B. Stalagmite incrusting some of the bones, and formed before the mud was introduced.

C. C. Stalagmite formed since the introduction of the mud, and spreading horizontally over its surface.

D. Insulated stalagmite on the surface of the mud.

E. E. Stalactites hanging from the roof above the stalagmites.

Fig. 3. Ground plan of the cave, by W. Salmond, Esq. showing its extent, ramifications, and the fissures by which is is intersected.

## PLATE XVII.

1. Portion of the left upper jaw of the modern hyæna from the Cape.

2. Inside view of No. 1.

3. Analogous portion of the left upper jaw of the fossil hyæna from Kirkdale.

4. Inside view of No. 3, with the tooth of a water-rat adhering by stalagmite to a broken portion of the palate.

5. Fragment from Kirkdale, showing five incisor teeth of the upper jaw, much worn down, and the inside of the palate.

## PLATE XVIII.

1. Outside view of the right lower jaw of the modern Cape hyæna.

2. Analogous portion of lower jaw of the Kirkdale hyæna, being nearly one-third larger.

3. Inside view of No. 2.

## PLATE XIX.

1. Fragment of the right lower jaw of an hyæna, showing the convex surface of the jaw and its teeth, that lay uppermost in the den, to be deeply worn by friction, and to have received a polish. The enamel, and one-third of the substance of the teeth and bone on this side have been worn away.

2. Concave surface of No. 1, having no marks of friction, polish, or decay: the enamel on this side of the teeth is perfect and unchanged.

3. Fragment of the right lower jaw of a young hyæna, having the convex surface only polished as in No. 1; and showing the cavities in which the second set of teeth were rising to succeed the first set; one of which, the posterior

molar tooth, still remains in its place, having its enamel on this side worn away, as in the teeth of No. 1.

4. Inside or concave surface of No. 3, has suffered no friction or polish, and the enamel of the tooth is perfect and fresh as in No. 2.

5. Metatarsal bone of hyæna.

6, 7. Phalanges of the toe of an animal not ascertained.

8. Claw bone of the toe of an hyæna.

9, 10, 11. Metacarpal bone and two phalanges of the toe of hyæna.

12. Claw bone of the toe of an hyæna.

PLATE XX.

1. Canine tooth or tusk of a bear (Ursus spelæus).

2. Inside view of posterior molar tooth of the lower jaw on the left side of hyæna.

3. Outside view to No. 2.

4. Largest canine tooth or tusk of hyæna found at Kirkdale.

5. Tusk of an animal of the tiger kind.

6. Outside view of right posterior molar tooth of the lower jaw of a tiger.

7. Inside view of No. 6. On comparing 6 and 7 with 2 and 3, it will be observed that in 6 and 7, the angle near the middle part of the crown is less obtuse than in 2 and 3, and that the two lobes which project at the base of the crown of 2 and 3 are wanting in 6 and 7.

8. Tusk of fox.

9. Incisor tooth of fox.

10. Inside view of No. 9.

11. Small molar tooth of fox.

12. Great molar tooth of the right lower jaw of fox; outside view.

13. Inside view of No. 12.

14. Penultima of upper jaw, right side, of fox.

15. } Molar teeth of wolf.
16. }

17. } Inside view.
18. } Outside view of No. 17.

19. Tooth of an animal not ascertained.

20, 21, 22, 23, 24, 25, 26, 27. Outside and inside views of four molar teeth of an animal not ascertained: they are all extremely thin, and have deep furrows worn on them.

28, 29. Posterior tooth and penultima of a weasel, left upper jaw (twice the natural size).

30, 31. Two views of the same tooth of an animal not ascertained, perhaps a seal.

PLATE XXI.

1. Small molar tooth of a very young elephant, being the average size of those found in the den.

2. Fragment of a still younger elephant's tooth.

3. Molar tooth of upper jaw of rhinoceros.

4. Inside view of molar tooth of lower jaw of rhinoceros.

5. Crown of No. 4, as seen from above.

6. Outside view of No. 4.

7. Molar tooth of the upper jaw of a horse.

8. } Two views of a molar tooth of hippopotamus not yet
9. } worn down.

10. Molar tooth of hippopotamus, having the summits of the crown worn down.

PLATE XXII.

1. Posterior molar tooth of the lower jaw of an ox.

2. Crown of No. 1.

3. Posterior molar tooth of the right lower jaw of a species of deer.

4. Molar tooth of the upper jaw of an ox.

5. Molar tooth of the lower jaw of a calf.

6. Side view of No. 5.

7. Molar tooth of the upper jaw of an ox.

8. Outside view of No. 7.

9. Molar tooth of the upper jaw of a very large species of deer, equalling in size the largest elk, but differing in form.

10. Outside view of No. 9.

11. Molar tooth of the upper jaw of a second species of deer, equalling in size the largest red deer.

12. Outside view of No. 11.

13. } Inside and outside views of a rising molar tooth of a
14. } third species of deer, of the size of a large fallow deer.

## Plate XXIII.

1. Outside view of a molar tooth of the lower jaw of a large species of deer.

2. Inside view of No. 1.

3. Base of the horn of a large deer, measuring nine inches and three quarters in circumference, which corresponds exactly in size with that of a very large English red deer in the Anatomy School at Oxford.

4. Base of a horn similar to No. 1, having two antlers near its lower extremity, and measuring seven inches and three quarters in circumference.

5. Base of a deer's horn, having the lowest antler at the distance of three inches and a half from the lower extremity, and measuring eight inches in circumference.

PLATE XXIV.

1. Coronary bone of a horse.
2. First phalangal bone of a very large ox; side view.
3. Under side of No. 2.
4, 5. Astragalus of a large ox: two different sides of the same bone.
6. Album græcum, showing a small sphere adhering to the larger one, and an indentation of the sides of both by pressure from a third sphere.
7. Astragalus of hyæna.
8. Side view of No. 7.
9. Astragalus of fox.
10. Side view of No. 9.
11. Astragalus of water-rat.
12. Os calcis of water-rat.
13. Os calcis of fox.
14. Os calcis of rabbit.
15, 16. Internal metatarsal bone of rabbit, having lost the epiphysis.
17, 18. Metatarsal bone of rabbit, retaining the epiphysis at the lower extremity.

PLATE XXV.

1. Lower jaw of a water-rat.
2. Lower incisor tooth of No. 1.
3. Upper incisor of water-rat.
4 Anterior molar tooth of lower jaw of water-rat.
5. No. 4, magnified.
6. Crown of No. 4, magnified.
7. Jaw of a mouse.
8 and 9. Teeth of No. 7, magnified four times.

10. Anterior molar tooth of the upper jaw of a rabbit.

11. Os innominatum of a young water-rat.

12. Tibia of a water-rat.

13. Lower epiphysis of femur of water-rat, twice magnified.

14. Femur of water-rat, twice magnified.

15. Ulna of water-rat.

16. Tail vertebra of water-rat.

17. Anterior extremity of No. 16.

18. Posterior extremity of No. 16.

19. Right ulna of a raven; anterior extremity.

20. Outside view of No. 19, showing the points of attachment of the quill feathers.

21. Right ulna of a raven, showing the other extremity of No. 19.

22, 23. Other views of No. 20, showing the cavity to be nearly filled with stalagmite.

24. Right ulna of a lark, showing the attachments of the quill feathers.

25. Inside view of No. 24.

26. Left ulna of a very large species of pigeon.

27. Inside view of No. 26.

28. Right coracoid process of the scapula of a small species of duck or widgeon.

29. Inside view of No. 28.

30. Tusk of the upper jaw of a large hog, polished obliquely near its apex, and having a molar tooth of hog adhering to it, near its base, by an ochreous crust.

31. View of the opposite side of No. 30.

32. Large molar tooth of hog in a fragment of the lower jaw, slightly incrusted with ochre.

33. Small molar tooth of hog.

## PLATE XXVI.

Vertical section of the great cave at Gailenreuth, near Bamberg, in Franconia; drawn from a sketch made on the spot by Professor Buckland, A. D. 1816.

A. Entrance passage, varying from five to eight feet in height, terminated externally by an open mouth in the steep side of a hill, and internally expanding into the cavern B.: a few bones are scattered irregularly along the floor.

B. First large chamber, having stalactites of all sizes hanging from its roof, and numerous bones of bears scattered on its floor.

C. Second chamber, separated from B by a perpendicular precipice, but having, probably, other lateral communications with it. On its floor the bones lie scattered more abundantly than in B.

D. Large aperture, descending obliquely downwards from C, and having cart loads of loose bones in it.

E. Mass composed chiefly of bones cemented by stalagmite, and forming a compact breccia.

F. Very long and low passage, connecting the chamber C with the vertical fissure G. The length of this passage is not expressed, for want of room; it can be traversed only by crawling on the hands and knees.

G. Vertical fissure of considerable depth, and about three feet in breadth; the only mode of descent is by supporting the hands and feet on niches cut in the opposite sides of the fissure.

H. Oven-shaped cavity, which has been produced artificially by extracting bones and skulls from the osseous breccia.

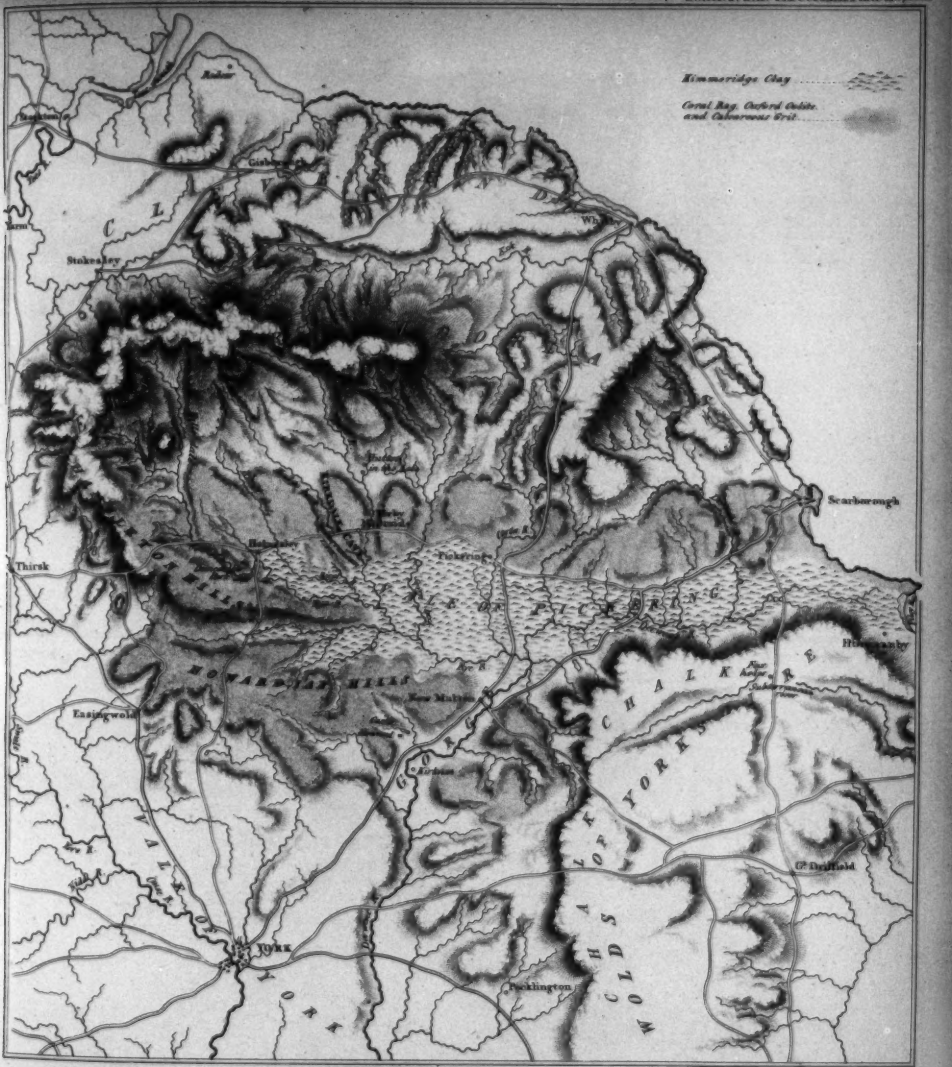

Kimmeridge Clay
Coral Rag, Oxford Oolite, and Calcareous Grit
Scarborough
Thirsk
Pickering
VALE OF PICKERING
HOWARDIAN HILLS
CHALK
YORKS WOLDS
York
Malton
New Malton
Easingwold
Stokesley
Driffield
Pocklington

Fig. 1

Fig. 2.

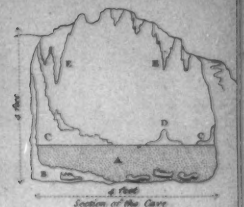
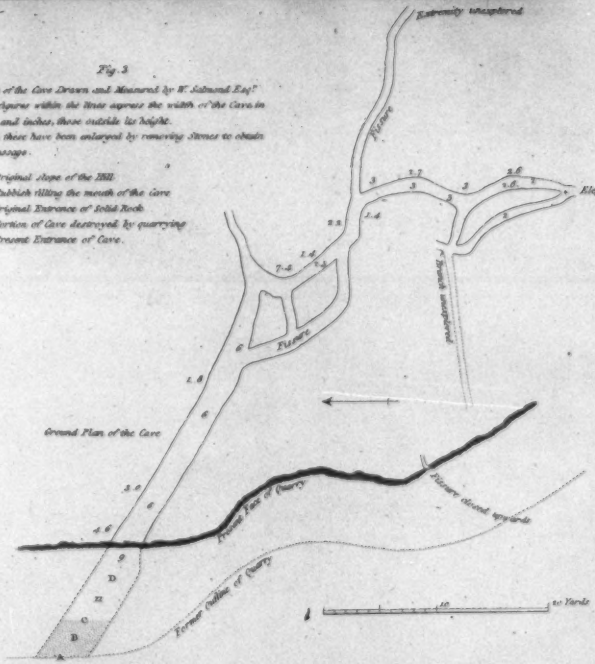



Fig. 3

Plan of the Cave Drawn and Measured by W. Salmond Esq^r
The figures within the lines express the width of the Cave in feet and inches, those outside its height.
Both these have been enlarged by removing Stones to obtain a Passage.

A. Original Slope of the Hill
B. Rubbish filling the mouth of the Cave
C. Original Entrance of Solid Rock
D. Portion of Cave destroyed by quarrying
E. Present Entrance of Cave.




W. Buckland
T. Webster } del.

J^s Basire sc.

T. Wehner del.

J. Baum sc.

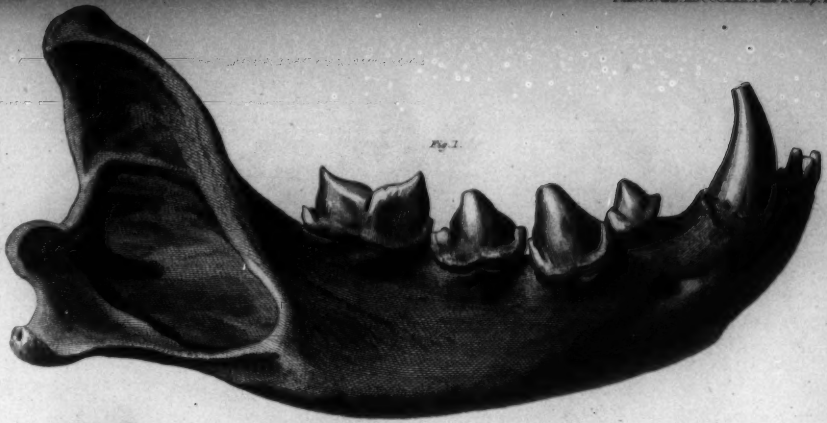


Fig. 1.

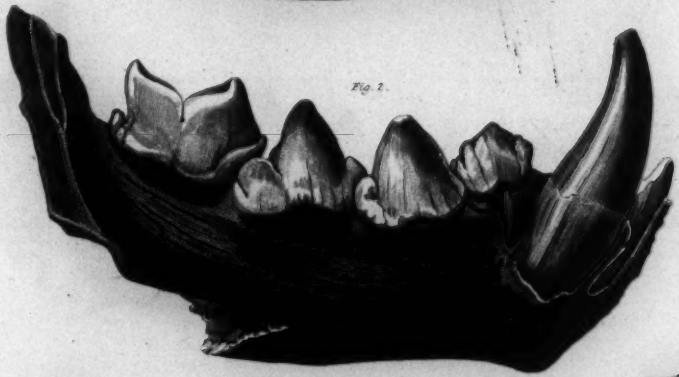


Fig. 2.

Fig. 3.

T. Webster
W. Clift, fc | del.

Fig. 1.

Fig. 3.

Fig. 2.

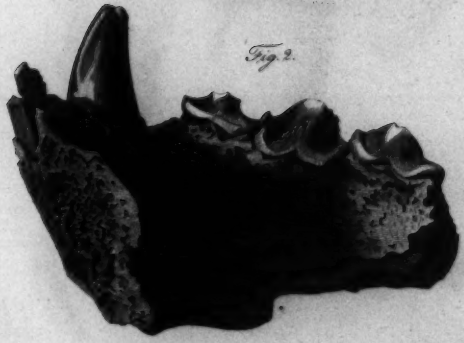


Fig. 4.

Fig. 5.

Fig. 6.

Fig. 8.

Fig. 7.

Fig. 9.

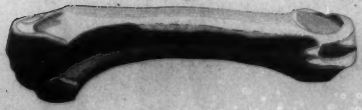


Fig. 10.

Fig. 11.

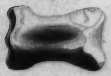
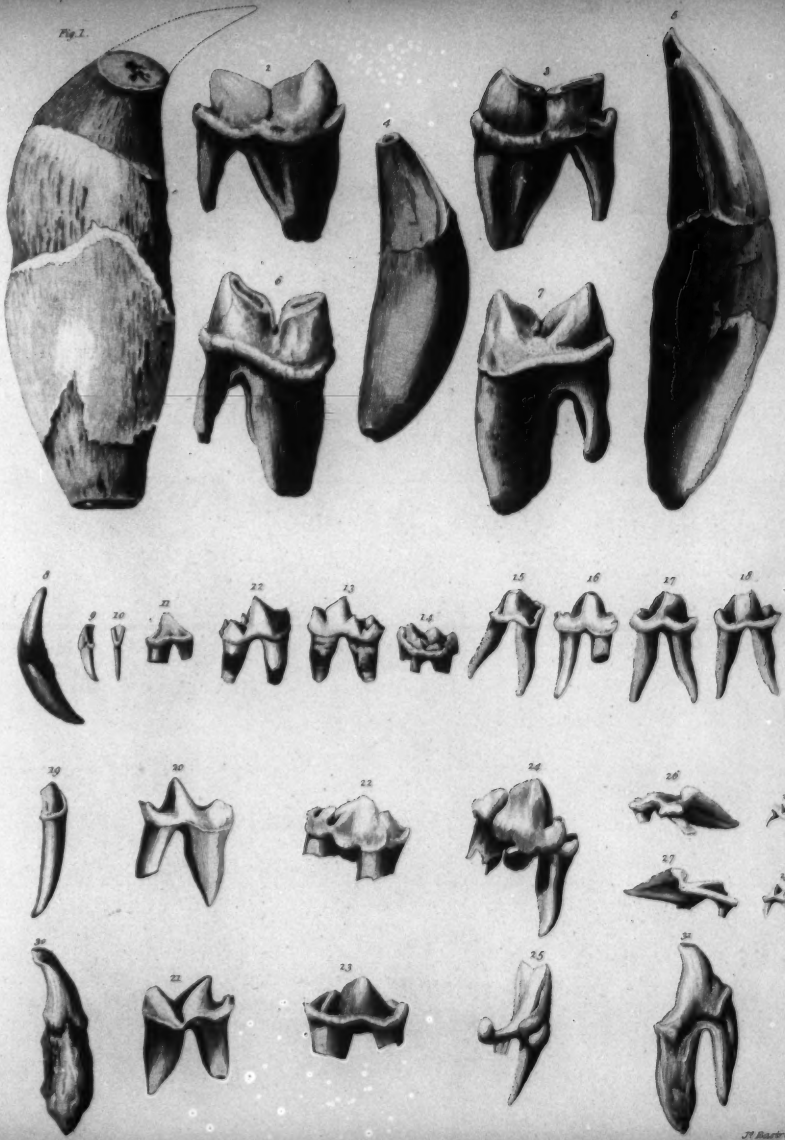


Fig. 12.

F. Cloncombe / T. Webster del.

J. Basire sc.

Fig. 1.




M. Martens

H. Barbre &c.

Fig. 2.

Fig. 3.

Fig. 1.

Fig. 4.

Fig. 5.

Fig. 7.

Fig. 6.

Fig. 8.

Fig. 9.

Fig. 10.

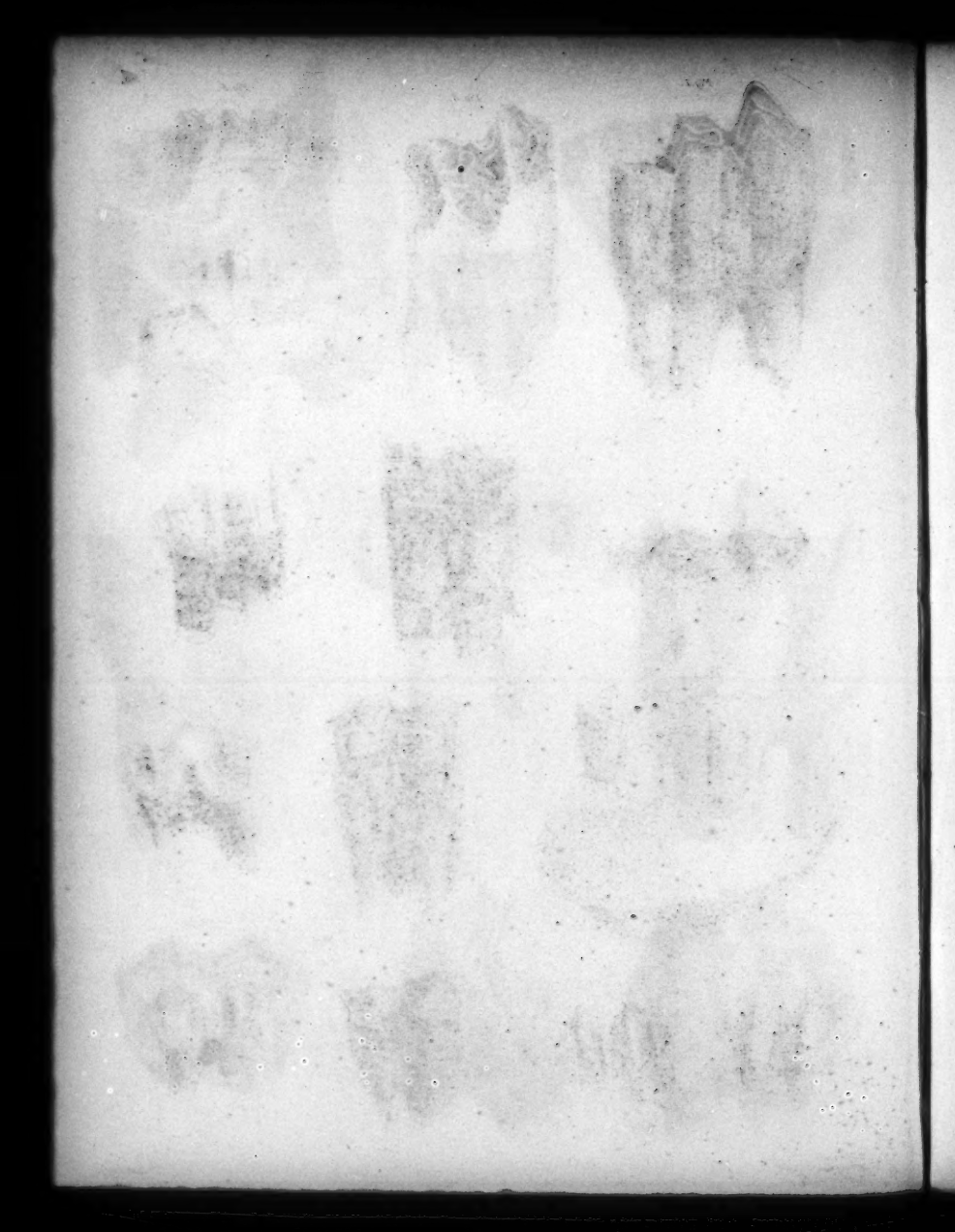


Fig. 1.

Fig. 4.

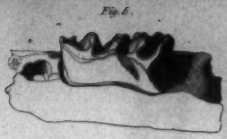


Fig. 5.

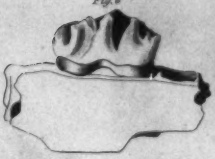


Fig. 6

Fig. 2.

Fig. 7.

Fig. 8.

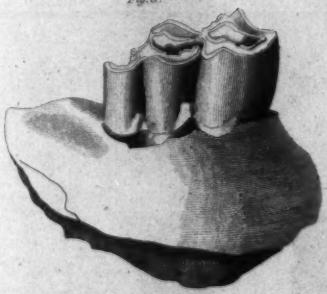


Fig. 3.

Fig. 9.

Fig. 10.

Fig. 13.

Fig. 14.

Fig. 11.

Fig. 12.

M. Norland.
F. Duncombe.
T. Webster. } del.t

Jn.t Basire sc.

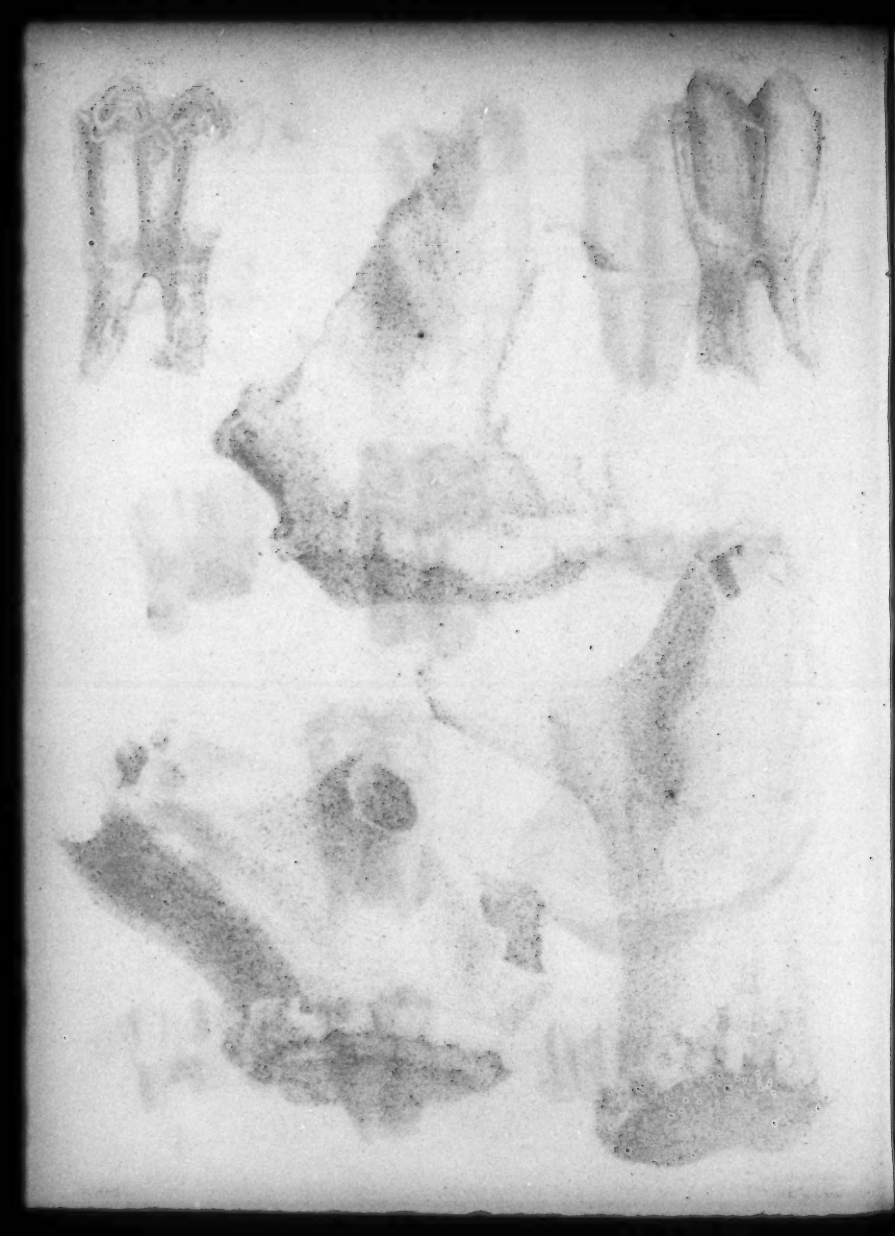


Fig. 1.

Fig. 2.

Fig. 3.

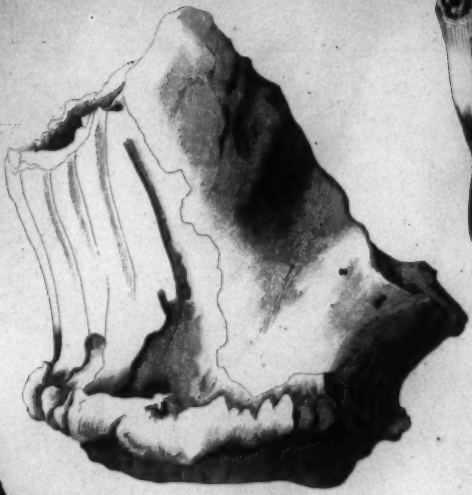
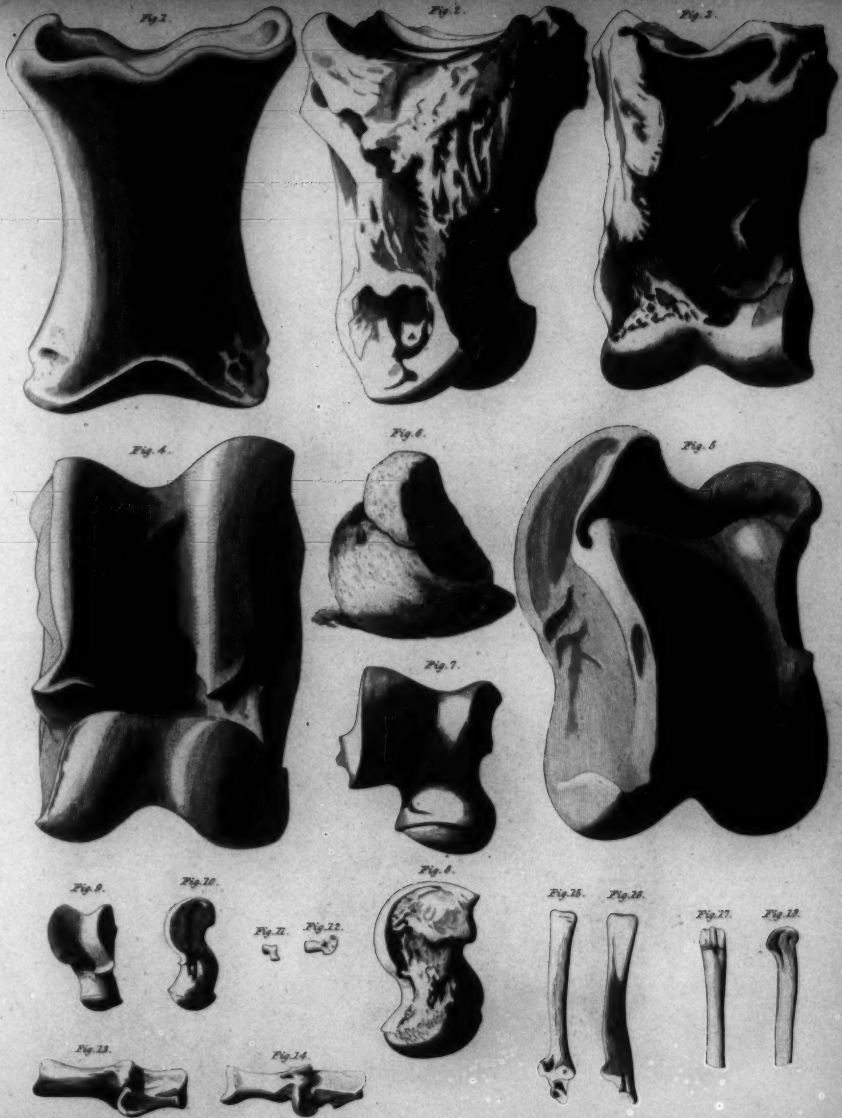


Fig. 5.

Fig. 4.

F. Duncombe del.

J.T. Basire sc.




T. Webster del.

H. Bastire sc.

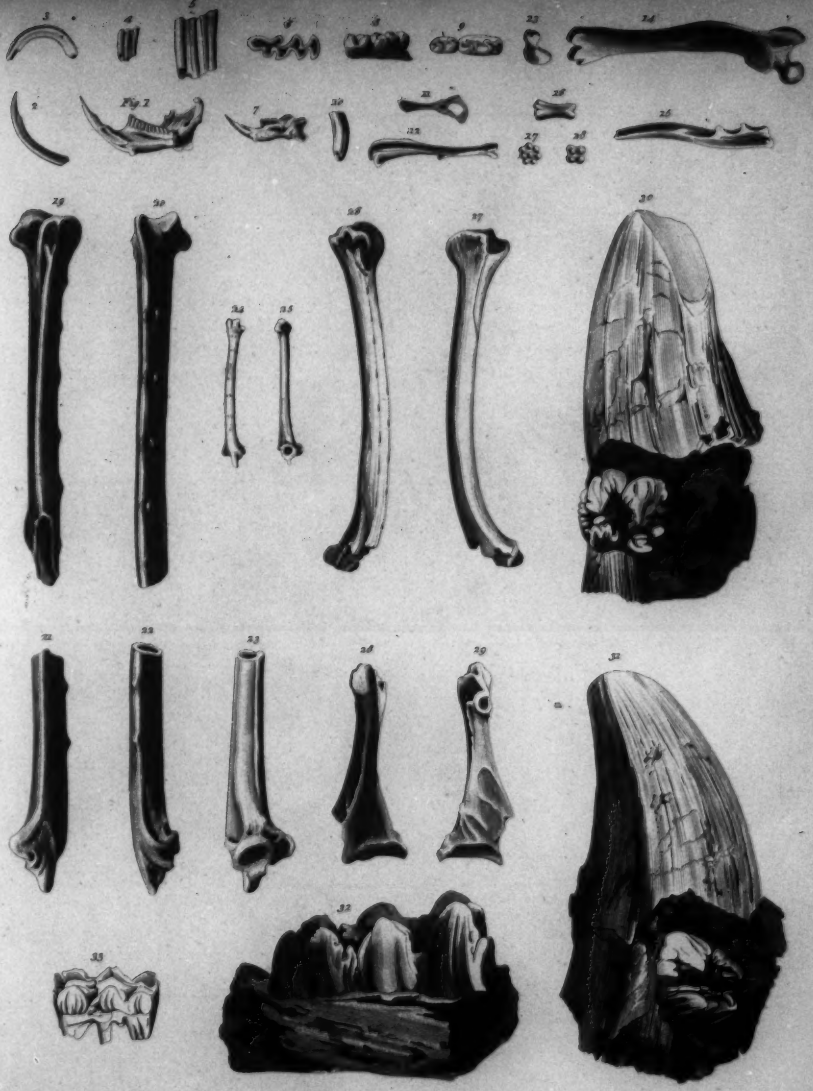


Fig 1
M. Mortimer,
T. Webster,
H.O Ford.
del.ts
J.T. Basire sc.

W. Buckland
T. Webster } del.

J. Basire sc.

XVII. *Communication of a curious appearance lately observed upon the Moon. By the Rev.* FEARON FALLOWS. *In a Letter addressed to* JOHN BARROW, *Esq. F. R. S.*

Read February 28, 1822.

Cape Town, Cape of Good Hope,
December 13, 1821.

DEAR SIR,

I TAKE the earliest opportunity of communicating to you a curious appearance which I lately observed upon the moon. My present means of making observations of this kind are indeed very limited, as the large telescopes, destined for the Cape Observatory, have not yet arrived. Still, however, it is right to have phenomena of this kind recorded, though the description may, from the want of proper instruments, be imperfect.

About eight o'clock in the evening of the 28th of November last, the sky being extremely clear, and the moon shining with a brilliancy which I never observed in England, my attention was drawn to a whitish spot on the dark part of the moon's limb, sufficiently luminous to be seen with the naked eye. Lest I might be mistaken, I requested Mr. FAYROR, the assistant astronomer, to look at the moon attentively, and inform me whether he could observe any bright appearance upon the dark part of it. We both agreed in the identity of the spot, and remarked that now and then it seemed to flash with considerable lustre. Mr. FAYROR having in his possession a good achromatic telescope, which Mr. TROUGHTON had

given him previous to our departure from England, I requested the loan of it for a few nights, so that I might be able to examine this appearance more minutely. Having directed the telescope to the moon, I immediately recognised the luminous spot, which seemed like a star of the sixth magnitude, and *three others* much smaller, but *one* of these more brilliant than the one we had seen with the naked eye. The largest spot was surrounded by a nebulous appearance. I could not perceive any thing of the kind about the small brilliant spot. The two others were similar to faint nebulæ, increasing in intensity towards the middle, but without any defined luminous point. As I am not yet in possession of a micrometer, by means of which the situation of these spots might be ascertained, you must rest satisfied with this imperfect description. On the evening of the 29th, the sky being equally favourable for observation as on the former one, I found that the large spot was, at the least, as bright as before, two others were nearly invisible, and the small brilliant spot had disappeared. I was unable to make any farther observations, as a strong south-east wind began to blow with great violence on the 30th, accompanied with rain, and which lasted several days. I wait with great anxiety for the next new moon, when, if the sky be clear, I shall not fail to examine it as carefully as my means at present will permit.

The telescope which I used is 4 feet long, and at the time of observation its magnifying power was 100.

I remain, Dear Sir,
very truly yours,
FEARON FALLOWS.

To John Barrow, Esq.

XVIII. *On the difference in the appearance of the teeth and the shape of the skull in different species of Seals.* By Sir Everard Home, *Bart. V. P. R. S.*

Read February 28, 1822.

At a time when geology is pursued with so much ardour, I am induced to lay before the Society the following facts respecting the skull and teeth of the seal, as their being known will be an advantage when incrusted or fossil remains of that animal are met with.

The accompanying drawings were made 30 years ago, at the time Mr. Hunter was preparing to lay before the Society some observations on the skulls of wolves and bears found in the caves of the principality of Bayreuth, in Germany. Among these, so great was the difference in the form of the skull of the young bear and the old, that where the jaws had been destroyed, it required the eye of an anatomist to determine that the skull really belonged to the bear.

While engaged upon that subject, I was surprised to find in the seal tribe, not only that the skull in the large species from the South Seas, differed exceedingly in its appearance from that of the smaller ones in the Northern Ocean, but that the teeth were equally unlike. At that time the facts had less importance; the study of geology being little attended to, the subject escaped my memory, till the recent strides made by Cuvier, Buckland, and others, have induced me to resume it.

## EXPLANATION OF THE PLATES.

### PLATE XXVII.

Represents the skull of the large seal so many years deposited in the British Museum, from the South Seas.

### PLATE XXVIII.

Shows the skull of a seal shot near the Orkney Isles, by a gentleman who went two years in succession for that purpose, and afterwards gave the skeleton to Mr. HUNTER. This animal had been known for 30 summers to come to the same rock, and lie basking in the sun; it had a grey beard.

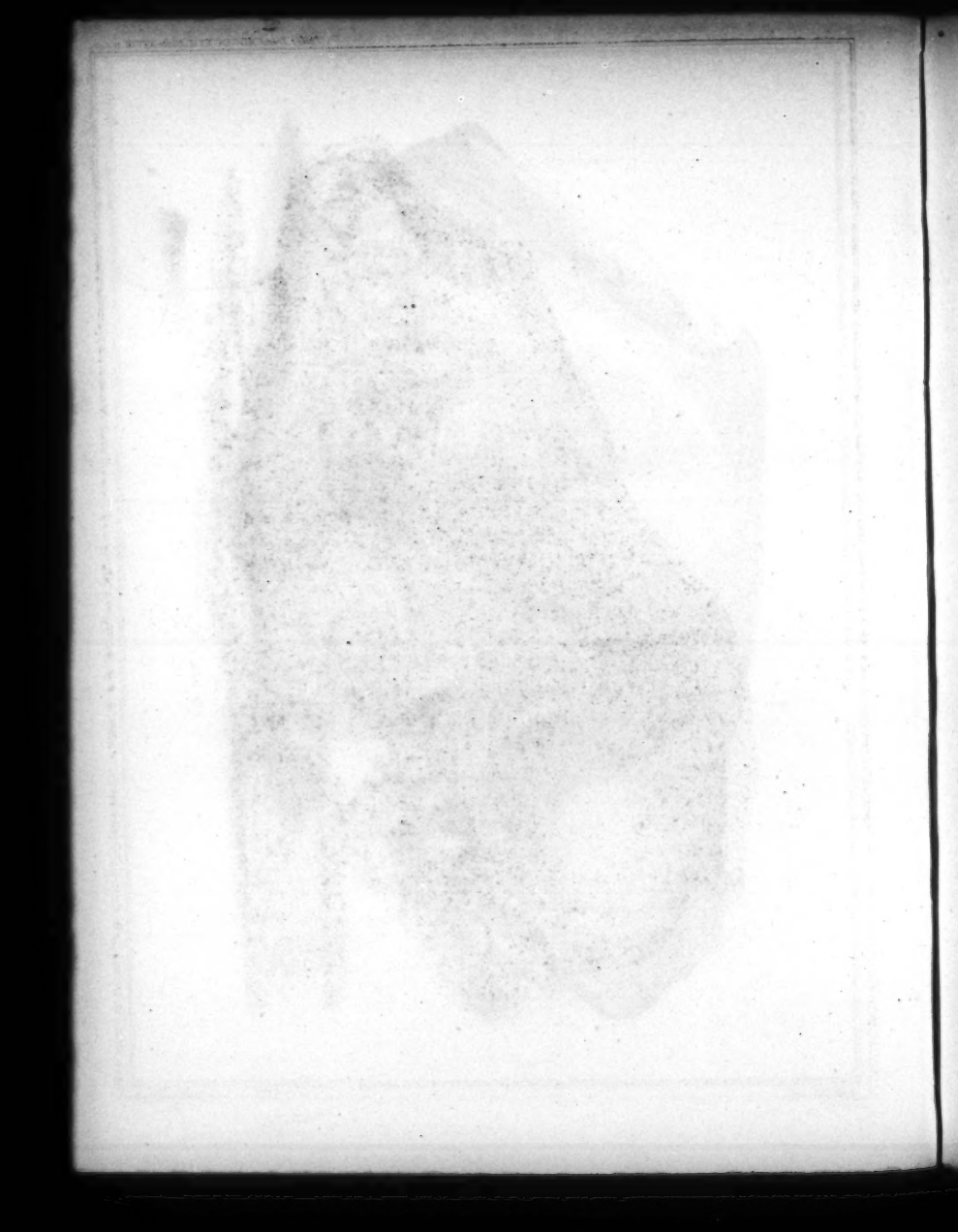
### PLATE XXIX.

Is taken from the skull of a seal in the Museum of the Royal College of Surgeons in Lincoln's Inn Fields, presented by Mr. CHEVALIER: this proves to have been brought by Mr. KEARN, in a Whaler, from New Georgia, near the ice towards the South Pole. The circumstance of most importance in this communication is, that in all the three skulls the teeth differ in form: this may arise from the different kinds of food on which the animals lived.

*From the Press of*
*W. NICOL, Successor to W. BULMER and Co.*
*Cleveland-row, St. James's,*
*London.*

Scale, eight inches to a foot.

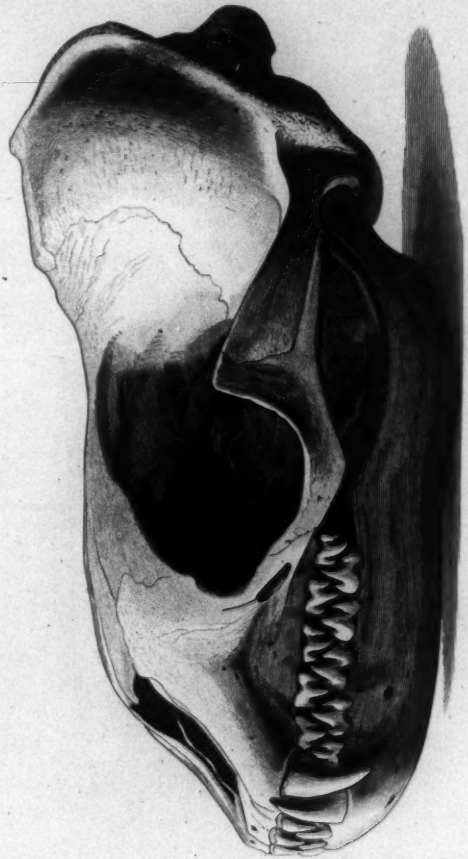
Plate Print. MDCCCXII. Plate XVII. p. 248.



Natural size

W.ᵐ Clift del.

S.ᵗ Bauer sc.



Scale. half an inch to one inch.

W. Clift del.

Jno. Basire sc.

# METEOROLOGICAL JOURNAL,

KEPT AT THE APARTMENTS

OF THE

# ROYAL SOCIETY,

BY ORDER OF THE

# PRESIDENT AND COUNCIL.

MDCCCXXII.

## METEOROLOGICAL JOURNAL

### for January, 1821.

| 1821 | Time. H. | M. | Therm. without. ° | Therm. within. ° | Barom. Inches. | Six's Therm. | | Winds. Points. | Str. | Weather. |
|---|---|---|---|---|---|---|---|---|---|---|
| Jan. 1 | 8 | 0 | 26 | 38 | 29,83 | 25 | | N | 1 | Cloudy and hazy. |
| | 2 | 0 | 29 | 44 | 29,82 | 30 | | ENE | 1 | Cloudy and hazy. |
| 2 | 8 | 0 | 25 | 39 | 29,72 | 25 | | E | 1 | Cloudy. |
| | 2 | 0 | 27 | 43 | 29,61 | 31 | | E | 1 | Cloudy. |
| 3 | 8 | 0 | 28 | 40 | 29,36 | 25 | | E | 1 | Cloudy. |
| | 2 | 0 | 32 | 41 | 29,31 | 33 | | E | 1,2 | Cloudy. [the night. |
| 4 | 8 | 0 | 27 | 38 | 29,35 | 27 | | N | 1 | Cloudy, a gale of wind in |
| | 2 | 0 | 30 | 43 | 29,36 | 32 | | NW | 1 | Cloudy. |
| 5 | 8 | 0 | 30 | 40 | 29,28 | 30 | | E | 1 | Cloudy and hazy. |
| | 2 | 0 | 32 | 43 | 29,21 | 33 | | E | 1 | Snow. |
| 6 | 8 | 0 | 36 | 41 | 29,10 | 30 | | SE | 1 | Cloudy and foggy. |
| | 2 | 0 | 40 | 46 | 29,17 | 42 | | E | 1 | Thick fog. |
| 7 | 8 | 0 | 35 | 41 | 29,19 | 35 | | N | 1 | Cloudy and foggy. |
| | 2 | 0 | 40 | 42 | 29,21 | 36 | | NE | 1 | Cloudy and hazy. |
| 8 | 8 | 0 | 37 | 41 | 29,16 | 35 | | E | 1 | Cloudy. |
| | 2 | 0 | 40 | 48 | 29,11 | 43 | | E | 1 | Cloudy and hazy. |
| 9 | 8 | 0 | 38 | 45 | 29,00 | 37 | | — | 1 | Thick fog. |
| | 2 | 0 | 41 | 49 | 28,98 | 42 | | SW | 1 | Fog. |
| 10 | 8 | 0 | 39 | 46 | 29,08 | 39 | | S | 1 | Cloudy. |
| | 2 | 0 | 44 | 47 | 29,11 | 45 | | WSW | 1 | Cloudy and hazy. |
| 11 | 8 | 0 | 41 | 48 | 29,06 | 39 | | E | 1 | Rain. |
| | 2 | 0 | 42 | 48 | 29,12 | 45 | | SE | 1 | Rain. |
| 12 | 8 | 0 | 45 | 50 | 29,23 | 39 | | S | 1,2 | Cloudy. |
| | 2 | 0 | 48 | 54 | 29,25 | 50 | | SSE | 1 | Cloudy and hazy. |
| 13 | 8 | 0 | 46 | 50 | 29,49 | 45 | | W | 1 | Fine. |
| | 2 | 0 | 49 | 54 | 29,51 | 50 | | SSW | 1 | Cloudy. |
| 14 | 8 | 0 | 44 | 51 | 29,22 | 44 | | N | 1 | Rain. |
| | 2 | 0 | 43 | 49 | 29,61 | 51 | | S | 1 | Cloudy. |
| 15 | 8 | 0 | 36 | 47 | 30,08 | 36 | | E | 1 | Hazy. |
| | 2 | 0 | 41 | 51 | 29,93 | 43 | | ESE | 1 | Cloudy. |
| 16 | 8 | 0 | 44 | 51 | 29,68 | 36 | | W | 1 | Fine. |
| | 2 | 0 | 47 | 55 | 29,87 | 48 | | WNW | 1 | Cloudy. |

Rain this Month 1,854 Inches.

## METEOROLOGICAL JOURNAL

### for January, 1821.

| 1821 | Time. H. | Time. M. | Therm. without. ° | Therm. within. ° | Barom. Inches. | Six's Therm. | Winds. Points. | Winds. Str. | Weather. |
|---|---|---|---|---|---|---|---|---|---|
| Jan. 17 | 8 | 0 | 39 | 52 | 30,13 | 38 | W | 1 | Hazy. |
| | 2 | 0 | 47 | 53 | 30,14 | 49 | WSW | 1 | Cloudy and hazy. |
| 18 | 8 | 0 | 46 | 51 | 30,21 | 39 | W | 1 | Cloudy. |
| | 2 | 0 | 51 | 57 | 30,23 | 52 | WSW | 1 | Cloudy and hazy. |
| 19 | 8 | 0 | 47 | 54 | 30,31 | 46 | S | 1 | Cloudy. |
| | 2 | 0 | 48 | 57 | 30,28 | 51 | WSW | 1 | Cloudy and hazy. |
| 20 | 8 | 0 | 44 | 53 | 30,30 | 42 | W | 1 | Hazy. |
| | 2 | 0 | 50 | 57 | 30,41 | 52 | WSW | 1 | Hazy and cloudy. |
| 21 | 8 | 0 | 36 | 52 | 29,61 | 36 | — | 1 | Thick fog. |
| | 2 | 0 | 44 | 53 | 30,61 | 51 | — | 1 | Fine. |
| 22 | 8 | 0 | 39 | 49 | 30,64 | 36 | W | 1 | Cloudy. |
| | 2 | 0 | 43 | 53 | 30,60 | 46 | W | 1 | Cloudy. |
| 23 | 8 | 0 | 40 | 52 | 30,73 | 39 | E | 1 | Cloudy. |
| | 2 | 0 | 42 | 57 | 30,76 | 45 | E | 1 | Cloudy. |
| 24 | 8 | 0 | 33 | 47 | 30,72 | 33 | E | 1 | Fine. |
| | 2 | 0 | 37 | 54 | 30,67 | 42 | W | 1 | Hazy. |
| 25 | 8 | 0 | 35 | 49 | 30,60 | 30 | SW | 1 | Cloudy. |
| | 2 | 0 | 44 | 54 | 30,60 | 45 | E | 1 | Foggy. |
| 26 | 8 | 0 | 39 | 52 | 30,58 | 35 | N by E | 1 | Cloudy and hazy. |
| | 2 | 0 | 41 | 55 | 30,54 | 45 | N | 1 | Cloudy. |
| 27 | 8 | 0 | 36 | 51 | 30,42 | 36 | SE | 1 | Cloudy. |
| | 2 | 0 | 38 | 55 | 30,35 | 42 | ESE | 1 | Cloudy. |
| 28 | 8 | 0 | 34 | 48 | 30,22 | 34 | SE | 1 | Cloudy. |
| | 2 | 0 | 38 | 47 | 30,21 | 40 | S by E | 1 | Cloudy. |
| 29 | 8 | 0 | 32 | 44 | 30,21 | 32 | E | 1 | Fine. |
| | 2 | 0 | 41 | 55 | 30,18 | 42 | S by E | 1 | Fine. |
| 30 | 8 | 0 | 43 | 47 | 30,24 | 39 | SW | 1 | Cloudy. |
| | 2 | 0 | 47 | 58 | 30,27 | 48 | W | 1 | Fine. |
| 31 | 8 | 0 | 44 | 51 | 30,35 | 43 | SW | 1 | Cloudy and hazy. |
| | 2 | 0 | 50 | 55 | 30,37 | 51 | SW | 1 | Cloudy. |

Rain this Month 1,854 Inches.

## METEOROLOGICAL JOURNAL

### for February, 1821.

| 1821 | Time. H. | Time. M. | Therm. without. ° | Therm. within. ° | Barom. Inches. | Six's Therm. | | Winds. Points. | Winds. Str. | Weather. |
|---|---|---|---|---|---|---|---|---|---|---|
| Feb. 1 | 8 | 0 | 46 | 53 | 30,38 | 45 | | SW | 1 | Cloudy. |
| | 2 | 0 | 50 | 57 | 30,35 | 52 | | WSW | 1,2 | Cloudy. |
| 2 | 8 | 0 | 47 | 54 | 30,17 | 45 | | W | 1 | Cloudy. |
| | 2 | 0 | 59 | 59 | 30,28 | 61 | | NW | 1 | Fine. |
| 3 | 8 | 0 | 37 | 52 | 30,33 | 36 | | W | 1 | Fine. |
| | 2 | 0 | 47 | 56 | 30,23 | 49 | | S | 1,2 | Cloudy. |
| 4 | 8 | 0 | 43 | 51 | 29,98 | 41 | | S | 1 | Cloudy. |
| | 2 | 0 | 45 | 51 | 29,93 | 47 | | SWbyS | 1 | Cloudy. |
| 5 | 8 | 0 | 33 | 48 | 30,59 | 33 | | N | 1 | Hazy. |
| | 2 | 0 | 42 | 56 | 30,71 | 54 | | NW | 1 | Fine. |
| 6 | 8 | 0 | 35 | 48 | 30,77 | 32 | | W by S | 1 | Hazy. |
| | 2 | 0 | 42 | 56 | 30,77 | 44 | | W by S | 1 | Fine. |
| 7 | 8 | 0 | 34 | 49 | 30,70 | 34 | | SW | 1 | Fine. |
| | 2 | 0 | 43 | 54 | 30,68 | 42 | | S | 1,2 | Fine. |
| 8 | 8 | 0 | 37 | 50 | 30,62 | 36 | | SSW | 1 | Fine. |
| | 2 | 0 | 46 | 58 | 30,54 | 47 | | SSE | 1 | Fine. |
| 9 | 8 | 0 | 36 | 51 | 30,23 | 35 | | SE | 1 | Hazy. |
| | 2 | 0 | 45 | 59 | 30,08 | 46 | | NNE | 1 | Fine. |
| 10 | 8 | 0 | 40 | 51 | 30,24 | 36 | | NE | 1,2 | Cloudy. |
| | 2 | 0 | 45 | 55 | 30,31 | 45 | | E | 1 | Fine. |
| 11 | 8 | 0 | 36 | 49 | 30,35 | 36 | | E | 1 | Hazy and cloudy. |
| | 2 | 0 | 40 | 51 | 30,28 | 44 | | E | 1 | Fine. |
| 12 | 8 | 0 | 34 | 47 | 30,23 | 33 | | N | 1 | Hazy. |
| | 2 | 0 | 40 | 54 | 30,23 | 41 | | NNE | 1 | Fine. |
| 13 | 8 | 0 | 35 | 48 | 30,29 | 35 | | ESE | 1 | Cloudy. |
| | 2 | 0 | 39 | 51 | 30,28 | 40 | | N | 1 | Pleasant but cloudy. |
| 14 | 8 | 0 | 34 | 47 | 30,23 | 34 | | N | 1 | Cloudy and dark. |
| | 2 | 0 | 37 | 53 | 30,22 | 39 | | N | 1 | Cloudy. |
| 15 | 8 | 0 | 34 | 50 | 30,35 | 34 | | W | 1 | Thick fog. |
| | 2 | 0 | 36 | 53 | 30,38 | 38 | | E | 1 | Cloudy and hazy. |

Rain this Month 0,278 Inches.

## METEOROLOGICAL JOURNAL
### for February, 1821.

| 1821 | Time. H. | M. | Therm. without. ° | Therm. within. ° | Barom. Inches. | Six's Therm. | | Winds. Points. | Str. | Weather. |
|---|---|---|---|---|---|---|---|---|---|---|
| Feb. 16 | 8 | 0 | 33 | 48 | 30,51 | 32 | | NE | 1 | Cloudy. |
| | 2 | 0 | 38 | 51 | 30,51 | 39 | | N | 2 | Cloudy. |
| 17 | 8 | 0 | 32 | 48 | 30,40 | 32 | | S | 1 | Cloudy and hazy. |
| | 2 | 0 | 36 | 50 | 30,29 | 38 | | S | 1 | Cloudy and hazy. |
| 18 | 8 | 0 | 32 | 45 | 30,17 | 30 | | NNW | 1 | Cloudy. |
| | 2 | 0 | 37 | 45 | 30,12 | 38 | | W | 1 | Cloudy and hazy. |
| 19 | 8 | 0 | 31 | 43 | 30,24 | 30 | | N | 1 | Fine. |
| | 2 | 0 | 38 | 47 | 30,31 | 40 | | W | 1 | Cloudy but pleasant. |
| 20 | 8 | 0 | 28 | 42 | 30,27 | 28 | | WbyN | 1 | Hazy. |
| | 2 | 0 | 38 | 47 | 30,13 | 40 | | WSW | 1 | Cloudy. |
| 21 | 8 | 0 | 36 | 45 | 30,15 | 29 | | NW | 1 | Hazy. |
| | 2 | 0 | 43 | 50 | 30,16 | 44 | | N | 1 | Fine. |
| 22 | 8 | 0 | 36 | 47 | 30,27 | 35 | | E | 1 | Cloudy and hazy. |
| | 2 | 0 | 40 | 53 | 30,28 | 44 | | W | 1 | Cloudy. |
| 23 | 8 | 0 | 30 | 48 | 30,30 | 30 | | W | 1 | Cloudy. |
| | 2 | 0 | 40 | 57 | 30,24 | 41 | | W by S | 1 | Fine. |
| 24 | 8 | 0 | 31 | 49 | 30,15 | 31 | | W | 1 | Hazy. |
| | 2 | 0 | 40 | 52 | 30,11 | 42 | | SSW | 1 | Cloudy but pleasant. |
| 25 | 8 | 0 | 35 | 47 | 30,07 | 31 | | NE | 2 | Cloudy and hazy. |
| | 2 | 0 | 43 | 47 | 30,04 | 45 | | WSW | 1 | Cloudy and hazy. |
| 26 | 8 | 0 | 34 | 47 | 30,05 | 34 | | E | 1 | Cloudy. |
| | 2 | 0 | 34 | 47 | 30,07 | 43 | | E | 1 | Cloudy and hazy. |
| 27 | 8 | 0 | 25 | 43 | 29,88 | 25 | | E | 1 | Fine. |
| | 2 | 0 | 35 | 52 | 29,77 | 36 | | ESE | 1 | Fine. |
| 28 | 8 | 0 | 32 | 47 | 29,30 | 26 | | E | 1 | Cloudy; snow in the night. |
| | 2 | 0 | 33 | 49 | 29,21 | 35 | | NNE | 1 | Snow and sleet. |

Rain this Month 0,278 Inches.

## METEOROLOGICAL JOURNAL
### for March, 1821.

| 1821 | Time. | Therm. without. | Therm. within. | Barom. | Six's Therm. | | Winds. | | Weather. |
|---|---|---|---|---|---|---|---|---|---|
| | H. M. | ° | ° | Inches. | | | Points. | Str. | |
| Mar. 1 | 7 0 | 37 | 48 | 29,33 | 37 | | E | 1 | Cloudy. |
| | 2 0 | 46 | 52 | 29,38 | 47 | | ESE | 1 | Cloudy. |
| 2 | 7 0 | 40 | 54 | 29,80 | 38 | | SW | 1 | Fine. |
| | 2 0 | 47 | 60 | 29,34 | 49 | | SE | 1 | Rain. |
| 3 | 7 0 | 45 | 54 | 29,74 | 48 | | WSW | 1 | Cloudy. |
| | 2 0 | 51 | 59 | 29,72 | 52 | | W | 1 | Rain. |
| 4 | 7 0 | 48 | 54 | 29,61 | 45 | | W | 1 | Cloudy. |
| | 2 0 | 54 | 56 | 29,61 | 55 | | W | 1 | Fine. |
| 5 | 7 0 | 39 | 52 | 29,84 | 39 | | E | 1 | Cloudy. |
| | 2 0 | 36 | 56 | 29,94 | 54 | | NE | 1 | Cloudy. |
| 6 | 7 0 | 34 | 50 | 29,83 | 31 | | E | 1 | Cloudy. |
| | 2 0 | 40 | 55 | 29,62 | 40 | | E | 1 | Rain. |
| 7 | 7 0 | 41 | 51 | 29,52 | 39 | | W | 1 | Cloudy. |
| | 2 0 | 50 | 63 | 29,58 | 51 | | SW | 1 | Cloudy. |
| 8 | 7 0 | 45 | 55 | 29,21 | 45 | | W | 1 | Cloudy. |
| | 2 0 | 51 | 51 | 29,23 | 54 | | W NW | 1 | Cloudy. |
| 9 | 7 0 | 43 | 57 | 29,58 | 43 | | W by N | 1 | Fine. |
| | 2 0 | 54 | 60 | 29,51 | 55 | | SW | 1 | Rain. |
| 10 | 7 0 | 48 | 59 | 29,57 | 48 | | SW | 1 | Fine. |
| | 2 0 | 57 | 66 | 29,65 | 59 | | SSW | 1 | Fair. |
| 11 | 7 0 | 44 | 57 | 29,79 | 43 | | W | 1 | Fine. |
| | 2 0 | 52 | 57 | 29,82 | 58 | | W | 1 | Fine. |
| 12 | 7 0 | 42 | 55 | 29,92 | 41 | | W | 1 | Hazy. |
| | 2 0 | 51 | 63 | 29,95 | 54 | | W | 1 | Showery. |
| 13 | 7 0 | 42 | 55 | 30,00 | 41 | | W | 1 | Hazy. |
| | 2 0 | 52 | 66 | 30,02 | 54 | | W | 1 | Fine. |
| 14 | 7 0 | 44 | 58 | 30,07 | 42 | | NW | 1 | Fine. |
| | 2 0 | 54 | 65 | 30,16 | 49 | | NNE | 1 | Fine and clear. |
| 15 | 7 0 | 37 | 54 | 30,36 | 37 | | SW | 1 | Fine. |
| | 2 0 | 48 | 66 | 30,38 | 53 | | SW | 1 | Fine. |
| 16 | 7 0 | 41 | 57 | 30,30 | 37 | | E | 1 | Hazy. |
| | 2 0 | 52 | 65 | 30,24 | 52 | | S | 1 | Fine. |

Rain this Month 1,917 Inches.

## METEOROLOGICAL JOURNAL

### for March, 1821.

| 1821 | Time. H. | M. | Therm. without. ° | Therm. within. ° | Barom. Inches. | Six's Therm. | Winds. Points. | Str. | Weather. |
|---|---|---|---|---|---|---|---|---|---|
| Mar. 17 | 7 | 0 | 39 | 56 | 30,06 | 38 | W | 1 | Fog. |
| | 2 | 0 | 50 | 64 | 29,93 | 52 | SW | 2 | Fine. |
| 18 | 7 | 0 | 42 | 54 | 29,48 | 39 | W | 1 | Fine. |
| | 2 | 0 | 48 | 56 | 29,45 | 52 | WNW | 2 | Cloudy and showery. |
| 19 | 7 | 0 | 39 | 53 | 29,20 | 38 | W | 1 | Fine. |
| | 2 | 0 | 46 | 56 | 29,18 | 48 | W by N | 2 | Cloudy. |
| 20 | 7 | 0 | 40 | 51 | 29,30 | 37 | W | 1 | Fine. |
| | 2 | 0 | 47 | 60 | 29,27 | 49 | NW | 1 | Cloudy, but pleasant. |
| 21 | 7 | 0 | 40 | 54 | 29,23 | 38 | W | 1 | Cloudy. |
| | 2 | 0 | 45 | 60 | 29,33 | 49 | N | 1 | Fine. |
| 22 | 7 | 0 | 39 | 53 | 29,53 | 37 | E | 1 | Fine. |
| | 2 | 0 | 45 | 59 | 29,75 | 46 | N by E | 1 | Fine, rather showery. |
| 23 | 7 | 0 | 36 | 53 | 30,05 | 34 | NNE | 1 | Fine. |
| | 2 | 0 | 47 | 59 | 30,07 | 47 | NW | 1 | Cloudy. |
| 24 | 7 | 0 | 40 | 52 | 29,84 | 36 | S | 2 | Cloudy. |
| | 2 | 0 | 48 | 56 | 29,68 | 50 | S | 1 | Cloudy. [wind in the night. |
| 25 | 7 | 0 | 42 | 51 | 29,35 | 42 | S by E | 1 | Rain: a violent storm of |
| | 2 | 0 | 50 | 58 | 29,38 | 52 | W | 1 | Cloudy. |
| 26 | 7 | 0 | 39 | 51 | 29,61 | 36 | W | 1 | Fine. |
| | 2 | 0 | 48 | 58 | 29,56 | 51 | S | 1 | Cloudy. |
| 27 | 7 | 0 | 41 | 51 | 29,22 | 40 | SSW | 1 | Cloudy. |
| | 2 | 0 | 47 | 56 | 29,33 | 50 | NNW | 1 | Cloudy. |
| 28 | 7 | 0 | 40 | 51 | 29,16 | 39 | S | 2 | Rain. |
| | 2 | 0 | 47 | 56 | 29,06 | 48 | SSE | 1 | Cloudy. |
| 29 | 7 | 0 | 42 | 52 | 29,06 | 42 | S | 1 | Rain. |
| | 2 | 0 | 47 | 59 | 29,21 | 48 | SW | 1 | Cloudy. |
| 30 | 7 | 0 | 38 | 53 | 29,63 | 37 | W | 1 | Fine. |
| | 2 | 0 | 48 | 69 | 29,71 | 50 | SW | 1 | Fine. |
| 31 | 7 | 0 | 41 | 51 | 29,41 | 39 | S | 2 | Cloudy, rain in the night. |
| | 2 | 0 | 48 | 56 | 29,38 | 51 | NNW | 1 | Cloudy. |

Rain this Month 1,917 Inches.

## METEOROLOGICAL JOURNAL
### for April, 1821.

| 1821 | Time. H. | M. | Therm. without. ° | Therm. within. ° | Barom. Inches. | Six's Therm. | | Winds. Points. | Str. | Weather. |
|---|---|---|---|---|---|---|---|---|---|---|
| April 1 | 7 | 0 | 37 | 51 | 29,58 | 36 | | W | 1 | Fine. |
| | 2 | 0 | 51 | 55 | 29,61 | 51 | | W | 1 | Fine. |
| 2 | 7 | 0 | 48 | 53 | 29,27 | 42 | | SSW | 1.2 | Rain. |
| | 2 | 0 | 55 | 58 | 29,25 | 59 | | W | 1 | Cloudy. |
| 3 | 7 | 0 | 42 | 53 | 29,31 | 40 | | W | 2 | Fair. |
| | 2 | 0 | 50 | 58 | 29,29 | 55 | | NW | 1 | Fine. |
| 4 | 7 | 0 | 41 | 54 | 29,31 | 39 | | W | 1 | Hazy. |
| | 2 | 0 | 53 | 61 | 29,32 | 53 | | WNW | 1 | Fine. |
| 5 | 7 | 0 | 41 | 54 | 29,45 | 40 | | N | 1 | Fine. |
| | 2 | 0 | 47 | 60 | 29,66 | 53 | | N | 1 | Fine. |
| 6 | 7 | 0 | 39 | 55 | 30,03 | 37 | | NW | 1 | Fine. |
| | 2 | 0 | 58 | 59 | 30,07 | 59 | | WNW | 1 | Cloudy. |
| 7 | 7 | 0 | 46 | 56 | 29,97 | 39 | | W | 1 | Rain. |
| | 2 | 0 | 59 | 60 | 30,06 | 59 | | NNW | 1 | Cloudy. |
| 8 | 7 | 0 | 50 | 57 | 30,12 | 49 | | W | 1 | Cloudy. |
| | 2 | 0 | 63 | 61 | 30,12 | 64 | | NW | 1 | Fine. |
| 9 | 7 | 0 | 48 | 58 | 30,02 | 47 | | W | 1 | Cloudy. |
| | 2 | 0 | 60 | 62 | 29,93 | 63 | | NNW | 1 | Fine. |
| 10 | 7 | 0 | 51 | 59 | 29,81 | 50 | | W | 1 | Rather hazy. |
| | 2 | 0 | 61 | 62 | 29,73 | 62 | | W | 1 | Cloudy. |
| 11 | 7 | 0 | 50 | 59 | 29,66 | 48 | | S | 1 | Cloudy. |
| | 2 | 0 | 60 | 63 | 29,58 | 62 | | S | 2 | Cloudy. |
| 12 | 7 | 0 | 44 | 57 | 29,36 | 42 | | W | 1 | Fine. |
| | 2 | 0 | 53 | 62 | 29,31 | 59 | | SW | 2 | Cloudy. |
| 13 | 7 | 0 | 45 | 57 | 29,32 | 41 | | W | 1 | Fine. |
| | 2 | 0 | 53 | 61 | 29,45 | 54 | | W | 2 | Cloudy. |
| 14 | 7 | 0 | 45 | 55 | 29,67 | 40 | | S | 1 | Fine. |
| | 2 | 0 | 61 | 57 | 29,32 | 62 | | S | 2 | Cloudy. |
| 15 | 7 | 0 | 42 | 53 | 29,52 | 39 | | SSW | 1 | Cloudy. |
| | 2 | 0 | 60 | 55 | 29,50 | 62 | | SSW | 1 | Showery. |
| 16 | 7 | 0 | 43 | 52 | 29,47 | 38 | | S | 1 | Fine. |
| | 2 | 0 | 61 | 57 | 29,40 | 63 | | S | 1 | Fine. |

Rain this Month 1,137 Inches.

## METEOROLOGICAL JOURNAL
### for April, 1821.

| 1821 | Time. H. | M. | Therm. without. ° | Therm. within. ° | Barom. Inches. | Six's Therm. | | Winds. Points. | Str. | Weather. |
|---|---|---|---|---|---|---|---|---|---|---|
| Apl. 17 | 7 | 0 | 40 | 53 | 29,42 | 38 | Rain this Month 1,137 Inches. | W | 1 | Fine, rather hazy. |
| | 2 | 0 | 59 | 58 | 29,64 | 59 | | W | 1 | |
| 18 | 7 | 0 | 45 | 53 | 29,64 | 41 | | W | 1 | Hazy. |
| | 2 | 0 | 55 | 58 | 29,69 | 56 | | NW | 1 | Cloudy. |
| 19 | 7 | 0 | 49 | 54 | 29,70 | 44 | | S | 2 | Cloudy. |
| | 2 | 0 | 53 | 55 | 29,56 | 55 | | S | 2 | Rain. [the night. |
| 20 | 7 | 0 | 50 | 54 | 29,51 | 49 | | SW | 1 | Cloudy; rained hard in |
| | 2 | 0 | 60 | 56 | 29,55 | 60 | | ESE | 1 | Cloudy dull weather, thunder and lightning at 8 P. M. |
| 21 | 7 | 0 | 53 | 56 | 29,73 | 50 | | NE | 1 | Cloudy. |
| | 2 | 0 | 58 | 58 | 29,82 | 60 | | N | 1 | Cloudy. |
| 22 | 7 | 0 | 48 | 56 | 29,97 | 45 | | N | 1 | Fine. |
| | 2 | 0 | 57 | 58 | 29,87 | 59 | | SE | 1 | Fine. |
| 23 | 7 | 0 | 52 | 57 | 29,56 | 49 | | E | 1 | Hazy. |
| | 2 | 0 | 66 | 62 | 29,49 | 68 | | E | 1 | Cloudy. |
| 24 | 7 | 0 | 56 | 58 | 29,40 | 53 | | S | 1 | Fine. |
| | 2 | 0 | 64 | 68 | 29,50 | 66 | | S | 1 | Fine. |
| 25 | 7 | 0 | 60 | 60 | 29,63 | 54 | | SE | 1 | Fine. |
| | 2 | 0 | 68 | 69 | 29,57 | 70 | | S | 1 | Fine. |
| 26 | 7 | 0 | 60 | 63 | 29,75 | 58 | | NNE | 1 | Hazy. |
| | 2 | 0 | 71 | 68 | 29,68 | 72 | | E | 1 | Fine. |
| 27 | 7 | 0 | 58 | 64 | 29,66 | 56 | | SW | 1 | Cloudy. |
| | 2 | 0 | 64 | 64 | 29,71 | 72 | | SW | 1 | Cloudy, but pleasant. |
| 28 | 7 | 0 | 59 | 62 | 29,81 | 52 | | WSW | 1 | Fine. |
| | 2 | 0 | 66 | 65 | 29,81 | 67 | | S | 1 | Fine. |
| 29 | 7 | 0 | 53 | 62 | 29,81 | 56 | | S | 1 | Fine. |
| | 2 | 0 | 61 | 67 | 29,84 | 67 | | S | 1 | Fine. |
| 30 | 7 | 0 | 53 | 61 | 30,01 | 51 | | N | 1 | Cloudy, rather hazy. |
| | 2 | 0 | 53 | 61 | 30,04 | 55 | | N | 1,2 | Cloudy. |

## METEOROLOGICAL JOURNAL

### for May, 1821.

| 1821 | Time. H. | Time. M. | Therm. without. ° | Therm. within. ° | Barom. Inches. | Six's Therm. | | Winds. Points. | Winds. Str. | Weather. |
|---|---|---|---|---|---|---|---|---|---|---|
| May 1 | 7 | 0 | 49 | 59 | 30,04 | 48 | | N | 1 | Cloudy and hazy. |
| | 2 | 0 | 56 | 61 | 29,97 | 57 | | ESE | 1 | Fine. |
| 2 | 7 | 0 | 53 | 59 | 29,87 | 48 | | N b E | 1 | Cloudy. |
| | 2 | 0 | 62 | 65 | 29,84 | 64 | | E | 1 | Cloudy. |
| 3 | 7 | 0 | 52 | 59 | 29,75 | 51 | | S | 1 | Cloudy. |
| | 2 | 0 | 65 | 62 | 29,69 | 66 | | S | 1 | Cloudy. |
| 4 | 7 | 0 | 55 | 61 | 29,60 | 53 | | W | 1 | Fine. |
| | 2 | 0 | 66 | 64 | 29,68 | 70 | | S | 1 | Fine. |
| 5 | 7 | 0 | 57 | 61 | 29,62 | 52 | | SW | 1 | Cloudy. |
| | 2 | 0 | 63 | 65 | 29,53 | 68 | | S | 1 | Fine. |
| 6 | 7 | 0 | 52 | 60 | 29,43 | 47 | | W | 1 | Cloudy. |
| | 2 | 0 | 59 | 62 | 29,49 | 64 | | WSW | 1 | Fine. |
| 7 | 7 | 0 | 49 | 59 | 29,80 | 45 | | W | 1 | Fine. |
| | 2 | 0 | 59 | 62 | 29,86 | 62 | | W | 1 | Fine. |
| 8 | 7 | 0 | 53 | 59 | 29,88 | 51 | | SW | 2 | Rain. |
| | 2 | 0 | 61 | 61 | 29,95 | 63 | | SW | 1 | Cloudy. |
| 9 | 7 | 0 | 47 | 55 | 30,14 | 43 | | W | 1 | Fine. |
| | 2 | 0 | 61 | 64 | 30,15 | 62 | | NNW | 1 | Fine. |
| 10 | 7 | 0 | 50 | 58 | 30,25 | 47 | | WNW | 1 | Fine. |
| | 2 | 0 | 60 | 59 | 30,21 | 62 | | W | 1 | Cloudy. |
| 11 | 7 | 0 | 51 | 57 | 30,01 | 47 | | W | 1 | Cloudy. |
| | 2 | 0 | 66 | 60 | 29,96 | 66 | | W by N | 1 | Cloudy. |
| 12 | 7 | 0 | 56 | 59 | 29,86 | 54 | | NW | 1 | Cloudy. |
| | 2 | 0 | 64 | 60 | 29,80 | 66 | | NW | 1 | Cloudy. |
| 13 | 7 | 0 | 48 | 56 | 29,38 | 44 | | W | 2 | Cloudy. |
| | 2 | 0 | 54 | 58 | 29,31 | 56 | | WSW | 1 | Cloudy, rain at intervals. |
| 14 | 7 | 0 | 46 | 54 | 29,30 | 42 | | N | 1 | Fine. |
| | 2 | 0 | 54 | 62 | 29,35 | 55 | | NW | 1 | Fine. |
| 15 | 7 | 0 | 46 | 56 | 29,17 | 44 | | SSW | 1 | Cloudy. |
| | 2 | 0 | 52 | 58 | 29,17 | 54 | | WSW | 1 | Fine. |
| 16 | 7 | 0 | 46 | 55 | 29,69 | 41 | | W | 1 | Fine. |
| | 2 | 0 | 56 | 61 | 29,81 | 56 | | W | 1 | Fine. |

Rain this Month 1,093 Inches.

## METEOROLOGICAL JOURNAL

### for May, 1821.

| 1821 | Time. H. | M. | Therm. without. ° | Therm. within. ° | Barom. Inches. | Six's Therm. | | Winds. Points. | Scr. | Weather. |
|---|---|---|---|---|---|---|---|---|---|---|
| May 17 | 7 | 0 | 47 | 55 | 29.95 | 43 | Rain this Month 1.093 Inches. | S | 1 | Cloudy. |
| | 2 | 0 | 52 | 56 | 29.91 | 56 | | SE | 1 | Rain. |
| 18 | 7 | 0 | 50 | 56 | 29,87 | 48 | | N | 1 | Fine. |
| | 2 | 0 | 60 | 61 | 30,03 | 61 | | W | 1 | Cloudy. |
| 19 | 7 | 0 | 47 | 56 | 30,20 | 45 | | N | 1 | Fine. |
| | 2 | 0 | 60 | 60 | 30,22 | 60 | | S | 1 | Fine. |
| 20 | 7 | 0 | 49 | 56 | 30,17 | 46 | | N | 1 | Cloudy. |
| | 2 | 0 | 55 | 57 | 30,18 | 61 | | E | 1 | Cloudy. |
| 21 | 7 | 0 | 47 | 55 | 30,14 | 42 | | SE | 1 | Fine. |
| | 2 | 0 | 51 | 57 | 30,05 | 52 | | E | 1 | Cloudy. |
| 22 | 7 | 0 | 47 | 54 | 29.99 | 41 | | N | 1 | Cloudy. |
| | 2 | 0 | 62 | 56 | 29,93 | 65 | | ESE | 1 | Fine. |
| 23 | 7 | 0 | 46 | 54 | 29,78 | 43 | | N | 1 | Cloudy. |
| | 2 | 0 | 50 | 55 | 29,76 | 52 | | E | 1 | Rain. |
| 24 | 7 | 0 | 42 | 52 | 29,92 | 39 | | N | 1 | Cloudy. |
| | 2 | 0 | 58 | 55 | 29,98 | 63 | | W | 1 | Fine. |
| 25 | 7 | 0 | 45 | 52 | 29,94 | 40 | | W | 1 | Cloudy. |
| | 2 | 0 | 60 | 55 | 29,74 | 58 | | W | 1 | Fine. |
| 26 | 7 | 0 | 42 | 53 | 29,73 | 38 | | NW | 1 | Fine. |
| | 2 | 0 | 48 | 58 | 29,77 | 57 | | N | 1 | Fine. |
| 27 | 7 | 0 | 44 | 53 | 29,86 | 37 | | N | 1 | Cloudy. |
| | 2 | 0 | 60 | 57 | 29,91 | 65 | | N | 1 | Cloudy, but pleasant. |
| 28 | 7 | 0 | 47 | 53 | 29,88 | 43 | | W | 1 | Cloudy. |
| | 2 | 0 | 54 | 56 | 29,95 | 56 | | W | 1 | Fine. |
| 29 | 7 | 0 | 46 | 52 | 30,08 | 42 | | W | 1 | Fine. |
| | 2 | 0 | 57 | 56 | 30,11 | 59 | | N | 1 | Fine. |
| 30 | 7 | 0 | 49 | 56 | 30,18 | 45 | | W | 1 | Fine. |
| | 2 | 0 | 57 | 57 | 30,18 | 62 | | SE | 1 | Fine. |
| 31 | 7 | 0 | 45 | 55 | 30,16 | 42 | | E | 1 | Cloudy. |
| | 2 | 0 | 57 | 63 | 30,11 | 59 | | E | 1 | Fine. |

## METEOROLOGICAL JOURNAL

### for June, 1821.

| 1821 | Time. H. | Time. M. | Therm. without. ° | Therm. within. ° | Barom. Inches. | Sir's Therm. | Winds Points. | Winds Str. | Weather. |
|---|---|---|---|---|---|---|---|---|---|
| June 1 | 7 | 0 | 50 | 58 | 30,04 | 55 | E | 1 | Fine. |
| | 2 | 0 | 68 | 62 | 30,03 | 68 | E | 1 | Cloudy. |
| 2 | 7 | 0 | 57 | 59 | 30,00 | 53 | N | 1 | Fine. |
| | 2 | 0 | 68 | 62 | 29,96 | 69 | E | 1 | Fine. |
| 3 | 7 | 0 | 53 | 60 | 29,91 | 57 | N | 1 | Cloudy. |
| | 2 | 0 | 66 | 66 | 29,84 | 70 | E | 1 | Fine. |
| 4 | 7 | 0 | 56 | 60 | 29,70 | 54 | NE | 1 | Rain. |
| | 2 | 0 | 63 | 63 | 29,63 | 67 | E | 1 | Fine. |
| 5 | 7 | 0 | 58 | 62 | 29,69 | 54 | W | 1 | Cloudy. |
| | 2 | 0 | 67 | 66 | 29,72 | 68 | W | 1 | Fine. |
| 6 | 7 | 0 | 57 | 62 | 29,82 | 54 | W | 1 | Fine. |
| | 2 | 0 | 66 | 66 | 29,90 | 69 | N | 1 | Cloudy. |
| 7 | 7 | 0 | 55 | 59 | 29,81 | 51 | W | 1 | Cloudy. |
| | 2 | 0 | 62 | 61 | 29,66 | 67 | W | 1 | Fine; rain at 4 P.M. [night. |
| 8 | 7 | 0 | 55 | 61 | 29,57 | 52 | N | 1 | Cloudy; much rain in the |
| | 2 | 0 | 58 | 60 | 29,71 | 63 | NE | 1 | Cloudy. |
| 9 | 7 | 0 | 49 | 58 | 29,80 | 45 | WNW | 1 | Cloudy. |
| | 2 | 0 | 56 | 57 | 29,78 | 59 | WSW | 1 | Cloudy. |
| 10 | 7 | 0 | 47 | 56 | 29,72 | 43 | WbyN | 1 | Cloudy. |
| | 2 | 0 | 52 | 54 | 29,72 | 55 | S | 1 | Fine. |
| 11 | 7 | 0 | 51 | 55 | 29,83 | 43 | NNE | 1 | Cloudy. |
| | 2 | 0 | 53 | 56 | 29,94 | 55 | N | 1 | Cloudy. |
| 12 | 7 | 0 | 50 | 55 | 30,16 | 46 | N | 1 | Fine. |
| | 2 | 0 | 54 | 57 | 30,23 | 55 | N | 1 | Cloudy. |
| 13 | 7 | 0 | 54 | 56 | 30,26 | 47 | N | 1 | Fine. |
| | 2 | 0 | 57 | 57 | 30,23 | 58 | N | 1 | Cloudy. |
| 14 | 7 | 0 | 52 | 55 | 30,28 | 44 | NE | 1 | Cloudy. |
| | 2 | 0 | 60 | 59 | 30,29 | 62 | W | 1 | Fine. |
| 15 | 7 | 0 | 52 | 57 | 30,30 | 49 | N | 1 | Hazy. |
| | 2 | 0 | 65 | 60 | 30,28 | 66 | W | 1 | Fine. |

Rain this Month 1,833 Inches.

## METEOROLOGICAL JOURNAL

### for June, 1821.

| 1821 | Time. H. | Time. M. | Therm. without. ° | Therm. within. ° | Barom. Inches. | Six's Therm. | | Winds. Points. | Winds. Str. | Weather. |
|---|---|---|---|---|---|---|---|---|---|---|
| June 16 | 7 | 0 | 55 | 57 | 30,21 | 52 | | W | 1 | Cloudy. |
| | 2 | 0 | 61 | 57 | 30,21 | 65 | | SW | 1 | Cloudy. |
| 17 | 7 | 0 | 53 | 58 | 30,28 | 51 | | N | 1 | Cloudy. |
| | 2 | 0 | 58 | 57 | 30,28 | 61 | | NW | 1 | Cloudy. |
| 18 | 7 | 0 | 53 | 57 | 30,32 | 50 | | NE | 1 | Cloudy and hazy. |
| | 2 | 0 | 64 | 65 | 30,30 | 65 | | N | 1 | Fine. |
| 19 | 7 | 0 | 54 | 57 | 30,24 | 48 | | NE | 1 | Fine. |
| | 2 | 0 | 62 | 65 | 30,18 | 65 | | NW | 1 | Fine. |
| 20 | 7 | 0 | 53 | 59 | 30,10 | 49 | | N | 1 | Cloudy. |
| | 2 | 0 | 59 | 62 | 30,06 | 63 | | NNE | 1 | Fine. |
| 21 | 7 | 0 | 53 | 57 | 30,06 | 48 | | NNE | 1 | Fine. |
| | 2 | 0 | 59 | 59 | 30,07 | 60 | | E | 1 | Cloudy. |
| 22 | 7 | 0 | 51 | 57 | 30,15 | 46 | | N | 1 | Fine. |
| | 2 | 0 | 57 | 58 | 30,16 | 60 | | S | 1 | Fine. |
| 23 | 7 | 0 | 53 | 52 | 30,17 | 51 | | NE | 1 | Cloudy. |
| | 2 | 0 | 58 | 58 | 30,17 | 59 | | S | 1 | Cloudy. |
| 24 | 7 | 0 | 53 | 57 | 30,13 | 48 | | N | 1 | Cloudy. |
| | 2 | 0 | 58 | 57 | 30,08 | 59 | | E | 1 | Cloudy. |
| 25 | 7 | 0 | 55 | 57 | 30,10 | 51 | | N by E | 2 | Cloudy. |
| | 2 | 0 | 65 | 61 | 30,11 | 65 | | E | 1 | Fine. |
| 26 | 7 | 0 | 56 | 58 | 30,12 | 52 | | N | 1 | Cloudy. |
| | 2 | 0 | 64 | 61 | 30,08 | 65 | | WSW | 1 | Fine. |
| 27 | 7 | 0 | 55 | 57 | 30,06 | 52 | | N | 1 | Fine. |
| | 2 | 0 | 65 | 66 | 30,07 | 66 | | N | 1 | Fine. |
| 28 | 7 | 0 | 58 | 59 | 30,15 | 55 | | N by W | 1 | Cloudy. |
| | 2 | 0 | 65 | 64 | 30,16 | 66 | | SSW | 1 | Fine. |
| 29 | 7 | 0 | 55 | 58 | 30,14 | 51 | | NE | 1 | Hazy. |
| | 2 | 0 | 69 | 66 | 30,08 | 70 | | | | Fine. |
| 30 | 7 | 0 | 60 | 61 | 29,90 | 55 | | SW | 1 | Fine. |
| | 2 | 0 | 72 | 67 | 29,88 | 73 | | S | 1 | Fine. |

Rain this Month 1,833 Inches.

## METEOROLOGICAL JOURNAL

### for July, 1821.

| 1821 | Time. H. | Time. M. | Therm. without. ° | Therm. within. ° | Barom. Inches. | Six's Therm. | | Winds. Points. | Winds. Str. | Weather. |
|---|---|---|---|---|---|---|---|---|---|---|
| July 1 | 7 | 0 | 61 | 64 | 29,58 | 59 | | W | 1 | Cloudy. |
| | 2 | 0 | 58 | 62 | 29,61 | 74 | | E | 1 | Rain. |
| 2 | 7 | 0 | 54 | 60 | 29,75 | 51 | | E | 1 | Rain. |
| | 2 | 0 | 60 | 61 | 29,78 | 68 | | NNE | 1 | Rain. |
| 3 | 7 | 0 | 51 | 59 | 29,77 | 52 | | E | 1 | Cloudy. |
| | 2 | 0 | 58 | 59 | 29,82 | 60 | | E | 1 | Fine. |
| 4 | 7 | 0 | 52 | 57 | 30,01 | 46 | | N | 1 | Fine. |
| | 2 | 0 | 60 | 61 | 30,09 | 61 | | N | 1 | Fine, rather cloudy. |
| 5 | 7 | 0 | 56 | 59 | 30,15 | 52 | | NW | 1 | Fine. |
| | 2 | 0 | 64 | 61 | 30,25 | 66 | | W | 1 | Fine. |
| 6 | 7 | 0 | 56 | 60 | 30,02 | 54 | | W | 1 | Hazy. |
| | 2 | 0 | 63 | 61 | 29,89 | 65 | | NW | 1 | Cloudy. |
| 7 | 7 | 0 | 55 | 58 | 29,78 | 52 | | NNW | 1 | Cloudy and hazy. |
| | 2 | 0 | 58 | 60 | 29,85 | 61 | | SSE | 1 | Fine. |
| 8 | 7 | 0 | 53 | 57 | 29,98 | 48 | | N | 1 | Cloudy. |
| | 2 | 0 | 59 | 57 | 30,04 | 60 | | SW | 1 | Fine. |
| 9 | 7 | 0 | 56 | 58 | 30,08 | 51 | | NNW | 1 | Fine, rather hazy. |
| | 2 | 0 | 65 | 63 | 30,07 | 67 | | NW | 1 | Fine. |
| 10 | 7 | 0 | 59 | 60 | 30,09 | 56 | | N | 1 | Cloudy and hazy. |
| | 2 | 0 | 66 | 62 | 30,09 | 67 | | WNW | 1 | Fine. |
| 11 | 7 | 0 | 55 | 60 | 30,13 | 53 | | W | 1 | Hazy. |
| | 2 | 0 | 65 | 61 | 30,11 | 67 | | W | 1 | Cloudy. |
| 12 | 7 | 0 | 55 | 58 | 30,07 | 50 | | E | 1 | Fine. |
| | 2 | 0 | 63 | 62 | 30,05 | 65 | | E | 1 | Fine. |
| 13 | 7 | 0 | 56 | 60 | 30,00 | 51 | | SW | 1 | Fine. |
| | 2 | 0 | 65 | 62 | 29,92 | 66 | | S by E | 1 | Fine. |
| 14 | 7 | 0 | 53 | 60 | 29,82 | 55 | | W | 1 | Cloudy. |
| | 2 | 0 | 66 | 64 | 29,78 | 67 | | W | 1 | Fine. |
| 15 | 7 | 0 | 56 | 60 | 29,71 | 53 | | W | 1 | Rain. |
| | 2 | 0 | 57 | 61 | 29,68 | 68 | | E | 1 | Rain. |
| 16 | 7 | 0 | 58 | 60 | 29,94 | 53 | | N | 1 | Fine. |
| | 2 | 0 | 57 | 64 | 30,02 | 58 | | N by W | 1 | Cloudy. |

Rain this Month 2,136 Inches.

## METEOROLOGICAL JOURNAL
### for July, 1821.

| 1820 | Time. H. | M. | Therm. without. ° | Therm. within. ° | Barom. Inches. | Six's Therm. | | Winds. Points. | Str. | Weather. |
|---|---|---|---|---|---|---|---|---|---|---|
| July 17 | 7 | 0 | 58 | 61 | 30,20 | 55 | | SSW | 1 | Cloudy. |
| | 2 | 0 | 67 | 64 | 30,26 | 68 | | W | 1 | Cloudy. |
| 18 | 7 | 0 | 58 | 61 | 30,30 | 55 | | E | 1 | Fine. |
| | 2 | 0 | 69 | 68 | 30,28 | 71 | | E | 1 | Fine. |
| 19 | 7 | 0 | 60 | 64 | 30,11 | 57 | | E | 1 | Cloudy. |
| | 2 | 0 | 72 | 71 | 29,99 | 73 | | E | 1 | Fine. |
| 20 | 7 | 0 | 63 | 65 | 29,82 | 59 | | W | 1 | Fine. |
| | 2 | 0 | 71 | 68 | 29,84 | 73 | | WSW | 1,2 | Cloudy. |
| 21 | 7 | 0 | 58 | 64 | 29,76 | 62 | | W | 1 | Fine. |
| | 2 | 0 | 69 | 69 | 29,77 | 71 | | W | 1 | Fine. |
| 22 | 7 | 0 | 58 | 64 | 29,58 | 56 | | S | 1,2 | Rain. |
| | 2 | 0 | 69 | 70 | 29,56 | 70 | | NW | 1 | Fine. |
| 23 | 7 | 0 | 59 | 62 | 29,58 | 55 | | S | 1 | Fine. |
| | 2 | 0 | 64 | 65 | 29,61 | 69 | | WNW | 1 | Fine. |
| 24 | 7 | 0 | 59 | 63 | 29,71 | 55 | | W | 1 | Cloudy; rain in the night. |
| | 2 | 0 | 67 | 66 | 29,74 | 68 | | SW | 1 | Fine. |
| 25 | 7 | 0 | 59 | 63 | 29,56 | 56 | | S | 1 | Rain. |
| | 2 | 0 | 68 | 66 | 29,76 | 70 | | S | 1 | Fine. |
| 26 | 7 | 0 | 59 | 63 | 29,88 | 55 | | W | 1,2 | Cloudy. |
| | 2 | 0 | 66 | 66 | 29,91 | 69 | | W | 1 | Cloudy. |
| 27 | 7 | 0 | 59 | 61 | 29,92 | 55 | | W | 1 | Fine. |
| | 2 | 0 | 67 | 66 | 29,94 | 68 | | NW | 1 | Fine. |
| 28 | 7 | 0 | 57 | 63 | 29,96 | 54 | | W | 1 | Hazy. |
| | 2 | 0 | 65 | 62 | 29,91 | 68 | | W | 1 | Fine. |
| 29 | 7 | 0 | 56 | 62 | 30,02 | 52 | | W | 1 | Fine. |
| | 2 | 0 | 67 | 63 | 30,01 | 68 | | WNW | 1 | Fine. |
| 30 | 7 | 0 | 55 | 61 | 29,93 | 55 | | SSE | 1 | Rain. |
| | 2 | 0 | 65 | 64 | 29,88 | 68 | | W | 1 | Rain. |
| 31 | 7 | 0 | 63 | 64 | 29,90 | 56 | | W | 1 | Fine. |
| | 2 | 0 | 71 | 66 | 29,91 | 72 | | W | 1 | Cloudy. |

Rain this Month 2,236 Inches.

## METEOROLOGICAL JOURNAL

### for August, 1821.

| 1821 | Time. H. | M. | Therm. without. ° | Therm. within. ° | Barom. Inches. | Six's Therm. | | Winds. Points. | Str. | Weather. |
|---|---|---|---|---|---|---|---|---|---|---|
| Aug. 1 | 7 | 0 | 61 | 64 | 29,93 | 60 | | SW | 1 | Cloudy. |
| | 2 | 0 | 70 | 66 | 29,89 | 72 | | W | 1 | Cloudy. |
| 2 | 7 | 0 | 61 | 63 | 30,07 | 57 | | N | 1 | Fine. |
| | 2 | 0 | 71 | 67 | 30,09 | 72 | | W | 1 | Fine. |
| 3 | 7 | 0 | 62 | 64 | 30,07 | 59 | | N | 1 | Cloudy. |
| | 2 | 0 | 71 | 66 | 30,08 | 73 | | N | 1 | Fine. |
| 4 | 7 | 0 | 62 | 64 | 30,06 | 60 | | S | 1 | Fine. |
| | 2 | 0 | 73 | 74 | 30,07 | 74 | | E | 1 | Fine. |
| 5 | 7 | 0 | 65 | 66 | 29,97 | 61 | | E | 1 | Fine. |
| | 2 | 0 | 76 | 72 | 29,96 | 77 | | E | 1 | Fine. |
| 6 | 7 | 0 | 67 | 68 | 29,87 | 63 | | W | 1 | Fine. |
| | 2 | 0 | 76 | 69 | 29,87 | 77 | | W | 1 | Fine. |
| 7 | 7 | 0 | 61 | 67 | 29,96 | 56 | | W | 1 | Fine. |
| | 2 | 0 | 69 | 69 | 29,97 | 73 | | NW | 1 | Cloudy. |
| 8 | 7 | 0 | 60 | 65 | 29,90 | 55 | | W | 1 | Cloudy. |
| | 2 | 0 | 64 | 63 | 29,64 | 69 | | W | 1 | Rain. |
| 9 | 7 | 0 | 60 | 64 | 29,49 | 57 | | W | 1 | Fine. |
| | 2 | 0 | 67 | 67 | 29,50 | 69 | | N | 1 | Fine. |
| 10 | 7 | 0 | 57 | 61 | 29,48 | 54 | | W | 1 | Cloudy. |
| | 2 | 0 | 66 | 65 | 29,47 | 68 | | W | 1,2 | Fine, rather cloudy. |
| 11 | 7 | 0 | 58 | 61 | 29,55 | 54 | | W | 1 | Cloudy. |
| | 2 | 0 | 67 | 64 | 29,64 | 68 | | WNW | 1 | Cloudy. |
| 12 | 7 | 0 | 56 | 61 | 29,85 | 50 | | W | 1 | Fine. |
| | 2 | 0 | 67 | 65 | 29,89 | 68 | | W | 1 | Fine. |
| 13 | 7 | 0 | 57 | 61 | 29,95 | 53 | | W | 1 | Cloudy. |
| | 2 | 0 | 68 | 65 | 29,95 | 70 | | WSW | 1 | Cloudy. |
| 14 | 7 | 0 | 58 | 62 | 29,80 | 58 | | W | 1 | Rain. |
| | 2 | 0 | 67 | 64 | 29,66 | 70 | | NNW | 1 | Cloudy. |
| 15 | 7 | 0 | 58 | 62 | 29,90 | 53 | | N | 1 | Fine. |
| | 2 | 0 | 68 | 68 | 29,97 | 70 | | NW | 1 | Fine. |
| 16 | 7 | 0 | 61 | 64 | 30,03 | 58 | | W | 1 | Cloudy. |
| | 2 | 0 | 71 | 69 | 30,04 | 72 | | W | 1 | Cloudy. |

Rain this Month 2,097 Inches.

## METEOROLOGICAL JOURNAL
### for August, 1821.

| 1821 | Time. H. | M. | Therm. without. ° | Therm. within. ° | Barom. Inches. | Six's Therm. | | Winds. Points. | Str. | Weather. |
|---|---|---|---|---|---|---|---|---|---|---|
| Aug. 17 | 7 | 0 | 64 | 65 | 30,10 | 62 | | W | 1 | Cloudy. |
| | 2 | 0 | 69 | 71 | 30,18 | 70 | | W | 1 | Fine. |
| 18 | 7 | 0 | 63 | 67 | 30,00 | 62 | | W | 1 | Cloudy dull weather. |
| | 2 | 0 | 67 | 67 | 30,15 | 70 | | W | 1 | Cloudy. |
| 19 | 7 | 0 | 58 | 64 | 30,16 | 54 | | N | 1 | Fine. |
| | 2 | 0 | 70 | 72 | 30,17 | 71 | | WSW | 1 | Fine. |
| 20 | 7 | 0 | 63 | 66 | 30,18 | 58 | | W | 1 | Cloudy and hazy. |
| | 2 | 0 | 74 | 74 | 30,19 | 75 | | E | 1 | Fair. |
| 21 | 7 | 0 | 64 | 67 | 30,17 | 60 | | E | 1 | Fine, rather hazy. |
| | 2 | 0 | 75 | 78 | 30,15 | 76 | | E | 1 | Fine. |
| 22 | 7 | 0 | 65 | 67 | 30,14 | 63 | | E | 1 | Hazy thick weather. |
| | 2 | 0 | 75 | 76 | 30,14 | 77 | | E | 1 | Fine. |
| 23 | 7 | 0 | 64 | 67 | 30,08 | 63 | | E | 1 | Cloudy and hazy. [Sun. |
| | 2 | 0 | 73 | 77 | 30,03 | 73 | | E | 1 | Fine. Therm. 83° in the |
| 24 | 7 | 0 | 64 | 68 | 29,95 | 61 | | E | 1 | Cloudy and hazy. |
| | 2 | 0 | 76 | 79 | 29,91 | 77 | | E | 1 | Fine. |
| 25 | 7 | 0 | 66 | 70 | 29,90 | 64 | | E | 1 | Cloudy. |
| | 2 | 0 | 74 | 74 | 29,90 | 77 | | S | 1 | Fine. |
| 26 | 7 | 0 | 63 | 65 | 29,94 | 62 | | N | 1 | Cloudy; rain in the night. |
| | 2 | 0 | 71 | 71 | 29,98 | 76 | | SE | 1 | Fine. |
| 27 | 7 | 0 | 62 | 64 | 30,11 | 58 | | E | 1 | Dull and Cloudy. |
| | 2 | 0 | 63 | 64 | 30,11 | 63 | | E | 1 | Cloudy. |
| 28 | 7 | 0 | 59 | 62 | 29,95 | 57 | | E | 1 | Cloudy. |
| | 2 | 0 | 60 | 63 | 29,87 | 63 | | E | 1 | Cloudy. |
| 29 | 7 | 0 | 57 | 63 | 29,76 | 54 | | E | 1 | Cloudy. |
| | 2 | 0 | 58 | 63 | 29,73 | 59 | | E | 1 | Rain. |
| 30 | 7 | 0 | 60 | 63 | 29,71 | 56 | | WNW | 1 | Cloudy. |
| | 2 | 0 | 69 | 63 | 29,71 | 71 | | SSE | 1 | Fine. |
| 31 | 7 | 0 | 62 | 65 | 29,67 | 61 | | SW | 1 | Cloudy. |
| | 2 | 0 | 68 | 67 | 29,67 | 70 | | W | 1 | Rain. |

Rain this Month 3,097 Inches.

## METEOROLOGICAL JOURNAL
### for September, 1821.

| 1821 | Time. H. | M. | Therm. without. ° | Therm. within. ° | Barom. Inches. | Six's Therm. | | Winds. Points. | Str. | Weather. |
|---|---|---|---|---|---|---|---|---|---|---|
| Sept. 1 | 7 | 0 | 62 | 65 | 29,85 | 61 | | W | 1 | Cloudy and hazy. |
| | 2 | 0 | 68 | 67 | 29,91 | 69 | | SW | 1 | Fine. |
| 2 | 7 | 0 | 63 | 65 | 30,02 | 61 | | W | 1 | Cloudy. |
| | 2 | 0 | 68 | 70 | 30,04 | 70 | | NW | 1 | Fine. |
| 3 | 7 | 0 | 62 | 65 | 29,96 | 62 | | S | 1 | Cloudy. |
| | 2 | 0 | 70 | 69 | 29,91 | 72 | | SW by S | 1 | Cloudy. |
| 4 | 7 | 0 | 65 | 67 | 29,84 | 63 | | SW | 1 | Cloudy. |
| | 2 | 0 | 70 | 69 | 29,77 | 72 | | W | 1 | Fine. |
| 5 | 7 | 0 | 63 | 65 | 29,77 | 60 | | W | 2 | Fine. |
| | 2 | 0 | 68 | 70 | 29,99 | 71 | | SW | 1 | Fine. |
| 6 | 7 | 0 | 65 | 66 | 29,92 | 61 | | S by E | 1 | Fine. |
| | 2 | 0 | 71 | 71 | 29,93 | 73 | | SW | 1,2 | Cloudy. |
| 7 | 7 | 0 | 67 | 67 | 29,66 | 67 | | S by E | 1 | Cloudy. |
| | 2 | 0 | 71 | 68 | 29,61 | 75 | | SW | 1 | Fine. |
| 8 | 7 | 0 | 61 | 65 | 29,59 | 60 | | W | 1 | Cloudy. |
| | 2 | 0 | 65 | 70 | 29,67 | 71 | | W | 1 | Fine. |
| 9 | 7 | 0 | 61 | 64 | 29,70 | 55 | | S | 1 | Fine. |
| | 2 | 0 | 68 | 65 | 29,57 | 69 | | SSE | 1 | Cloudy. |
| 10 | 7 | 0 | 57 | 63 | 29,66 | 53 | | W by N | 1 | Fine. |
| | 2 | 0 | 64 | 68 | 29,74 | 68 | | N N W | 1 | Fine. |
| 11 | 7 | 0 | 57 | 62 | 29,94 | 53 | | W | 1 | Fine. |
| | 2 | 0 | 64 | 67 | 29,99 | 65 | | WSW | 1 | Fine. |
| 12 | 7 | 0 | 58 | 62 | 29,73 | 59 | | SW | 1 | Rain. |
| | 2 | 0 | 65 | 66 | 29,62 | 67 | | W | 1 | Rain. |
| 13 | 7 | 0 | 57 | 61 | 29,90 | 54 | | W | 1 | Cloudy. |
| | 2 | 0 | 65 | 64 | 29,95 | 66 | | SSW | 1 | Cloudy, but pleasant. |
| 14 | 7 | 0 | 54 | 62 | 29,92 | 54 | | SW | 1 | Cloudy. |
| | 2 | 0 | 65 | 62 | 29,98 | 59 | | N by E | 1 | Cloudy. |
| 15 | 7 | 0 | 51 | 59 | 30,18 | 50 | | E | 1 | Foggy. |
| | 2 | 0 | 65 | 64 | 30,20 | 65 | | NW | 1 | Fine. |

Rain this Month 1,810 Inches.

## METEOROLOGICAL JOURNAL

### for September, 1821.

| 1821 | Time. H. | Time. M. | Therm. without. | Therm. within. | Barom. | Six's Therm. | | Winds. Points. | Winds. Str. | Weather. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | o | o | Inches. | | | | | |
| Sept. 16 | 7 | 0 | 62 | 63 | 30,20 | 61 | | W | 1 | Cloudy, rather hazy. |
| | 2 | 0 | 69 | 66 | 30,19 | 70 | | W | 1 | Fine. |
| 17 | 7 | 0 | 63 | 64 | 30,13 | 61 | | W | 1 | Cloudy. |
| | 2 | 0 | 70 | 68 | 30,06 | 71 | | NW | 1 | Cloudy. |
| 18 | 7 | 0 | 63 | 65 | 29,96 | 61 | | S | 1 | Fine. |
| | 2 | 0 | 69 | 68 | 29,87 | 70 | | NW | 1 | Fine. |
| 19 | 7 | 0 | 52 | 62 | 29,84 | 55 | | W | 1 | Fine. |
| | 2 | 0 | 66 | 65 | 29,90 | 68 | | N | 1 | Cloudy. |
| 20 | 7 | 0 | 54 | 60 | 29,95 | 50 | | W | 1 | Cloudy. |
| | 2 | 0 | 62 | 61 | 29,84 | 64 | | W | 1 | Cloudy. |
| 21 | 7 | 0 | 59 | 62 | 29,70 | 54 | | S | 1 | Cloudy. |
| | 2 | 0 | 65 | 64 | 29,68 | 66 | | W | 1 | Cloudy. |
| 22 | 7 | 0 | 60 | 62 | 29,72 | 58 | Rain this Month 1,810 Inches. | N | 1 | Fine; a storm of thunder and lightning in the night. |
| | 2 | 0 | 66 | 64 | 29,74 | 67 | | E | 1 | Fine. |
| 23 | 7 | 0 | 61 | 63 | 29,69 | 60 | | E | 1 | Cloudy. |
| | 2 | 0 | 66 | 63 | 29,66 | 67 | | E | 1 | Cloudy and hazy. |
| 24 | 7 | 0 | 57 | 60 | 29,62 | 53 | | WSW | 1 | Fine. |
| | 2 | 0 | 64 | 63 | 29,76 | 65 | | W | 1 | Cloudy. |
| 25 | 7 | 0 | 52 | 59 | 29,95 | 49 | | W | 1 | Fine, rather cloudy. |
| | 2 | 0 | 65 | 61 | 29,98 | 67 | | W | 1 | Fine. |
| 26 | 7 | 0 | 60 | 62 | 29,97 | 52 | | W | 1 | Cloudy. |
| | 2 | 0 | 67 | 65 | 29,96 | 68 | | W | 1 | Cloudy. |
| 27 | 7 | 0 | 59 | 61 | 29,85 | 55 | | W | 1 | Rainy dark weather. |
| | 2 | 0 | 63 | 64 | 29,89 | 67 | | W | 1 | Cloudy. |
| 28 | 7 | 0 | 55 | 60 | 29,92 | 52 | | W | 1 | Cloudy. |
| | 2 | 0 | 63 | 63 | 29,75 | 65 | | E | 1 | Fine. |
| 29 | 7 | 0 | 54 | 57 | 29,49 | 53 | | SW | 2 | Cloudy; a violent gale in the night. |
| | 2 | 0 | 60 | 60 | 29,53 | 63 | | E | 1 | Fine. |
| 30 | 7 | 0 | 49 | 58 | 29,78 | 40 | | W | 1 | Fine. |
| | 2 | 0 | 58 | 59 | 29,85 | 60 | | NW | 1 | Cloudy. |

## METEOROLOGICAL JOURNAL
### for October, 1821.

| 1821 | Time. | Therm. without. | Therm. within. | Barom. | Six's Therm. | | Winds. | | Weather. |
|---|---|---|---|---|---|---|---|---|---|
| | H. M. | ° | ° | Inches. | | | Points. | Str. | |
| Oct. 1 | 8 0 | 58 | 59 | 29,67 | 50 | | NW | 1 | Cloudy. |
| | 2 0 | 63 | 62 | 29,70 | 64 | | NW | 1,2 | Cloudy. |
| 2 | 8 0 | 52 | 57 | 30,08 | 48 | | NNW | 1 | Fine. |
| | 2 0 | 58 | 62 | 30,14 | 65 | | W | 1 | Fine. |
| 3 | 8 0 | 58 | 60 | 29,99 | 52 | | SW | 1 | Cloudy. |
| | 2 0 | 65 | 62 | 29,87 | 66 | | W | 1,2 | Cloudy. |
| 4 | 8 0 | 59 | 62 | 29,65 | 58 | | S | 1 | Rain. |
| | 2 0 | 61 | 62 | 29,49 | 65 | | ESE | 1 | Rain. |
| 5 | 8 0 | 49 | 57 | 29,79 | 47 | | NW | 1 | Fine. |
| | 2 0 | 56 | 61 | 29,93 | 62 | | NW | 1 | Fine. |
| 6 | 8 0 | 49 | 57 | 30,02 | 47 | | W | 1 | Fine. |
| | 2 0 | 60 | 60 | 30,03 | 61 | | W | 1 | Fine. |
| 7 | 8 0 | 57 | 59 | 30,04 | 50 | | W | 1 | Fine. |
| | 2 0 | 61 | 60 | 30,03 | 63 | | W | 1 | Cloudy. |
| 8 | 8 0 | 56 | 59 | 29,92 | 53 | | S | 2 | Rain. |
| | 2 0 | 58 | 62 | 30,03 | 61 | | N | 1 | Fine. |
| 9 | 8 0 | 48 | 56 | 30,26 | 45 | | E | 1 | Fine. |
| | 2 0 | 66 | 62 | 30,24 | 68 | | E | 1 | Fine. |
| 10 | 8 0 | 51 | 55 | 30,09 | 47 | | E | 1 | Fine. |
| | 2 0 | 59 | 63 | 29,98 | 59 | | E | 1 | Fine. |
| 11 | 8 0 | 49 | 57 | 29,76 | 48 | | E | 1 | Cloudy. |
| | 2 0 | 54 | 58 | 29,64 | 58 | | E | 1 | Rain. |
| 12 | 8 0 | 51 | 56 | 29,71 | 50 | | NW | 1 | Hazy and Cloudy. |
| | 2 0 | 56 | 58 | 29,88 | 56 | | SW | 1 | Fine. |
| 13 | 8 0 | 50 | 56 | 30,26 | 49 | | N | 1 | Fine, rather hazy. |
| | 2 0 | 56 | 56 | 30,31 | 57 | | SW | 1 | Cloudy. |
| 14 | 8 0 | 45 | 54 | 29,33 | 42 | | E | 1 | Hazy. |
| | 2 0 | 58 | 67 | 30,28 | 58 | | WSW | 1 | Cloudy. |
| 15 | 8 0 | 50 | 56 | 30,23 | 45 | | N | 1 | Rain. |
| | 2 0 | 58 | 58 | 30,20 | 53 | | NE | 1 | Fine. |
| 16 | 8 0 | 44 | 54 | 30,16 | 42 | | W | 1 | Fine, rather hazy. |
| | 2 0 | 54 | 57 | 30,14 | 52 | | N | 1 | Fine. |

Rain this Month 1,911 Inches.

## METEOROLOGICAL JOURNAL
### for October, 1821.

| 1821 | Time. H. | M. | Therm. without. ° | Therm. within. ° | Barom. Inches. | Sir's Therm. | | Winds. Points. | Str. | Weather. |
|---|---|---|---|---|---|---|---|---|---|---|
| Oct. 17 | 8 | 0 | 46 | 54 | 30,15 | 45 | | NW | 1 | Cloudy. |
| | 2 | 0 | 53 | 55 | 30,07 | 51 | | W | 1 | Cloudy. |
| 18 | 8 | 0 | 49 | 54 | 29,92 | 48 | | W | 1 | Rain. |
| | 2 | 0 | 59 | 60 | 29,89 | 60 | | W | 1 | Cloudy. |
| 19 | 8 | 0 | 50 | 55 | 29,89 | 49 | | W | 1 | Cloudy. |
| | 2 | 0 | 54 | 53 | 29,79 | 58 | | W | 1 | Cloudy. |
| 20 | S | 0 | 51 | 53 | 29,27 | 48 | | S | 2 | Cloudy. |
| | 2 | 0 | 53 | 55 | 29,92 | 56 | | NW | 1 | Rain. |
| 21 | 8 | 0 | 43 | 53 | 29,11 | 43 | | W | 1 | Fine. |
| | 2 | 0 | 49 | 56 | 29,17 | 53 | | WSW | 1 | Fine. |
| 22 | 8 | 0 | 45 | 53 | 29,12 | 43 | | S | 1 | Cloudy. |
| | 2 | 0 | 53 | 56 | 29,21 | 54 | | S | 1,2 | Fine. |
| 23 | 8 | 0 | 47 | 53 | 29,34 | 45 | | S | 2 | Cloudy. |
| | 2 | 0 | 50 | 53 | 29,21 | 52 | | E | 1 | Rain. |
| 24 | 8 | 0 | 44 | 53 | 29,38 | 43 | | S | 1 | Fine. |
| | 2 | 0 | 53 | 55 | 29,52 | 53 | | NW | 1 | Rain. |
| 25 | 8 | 0 | 43 | 53 | 29,91 | 41 | | W | 2 | Cloudy. |
| | 2 | 0 | 53 | 59 | 29,94 | 54 | | W | 1 | Rain. |
| 26 | 8 | 0 | 50 | 56 | 30,06 | 43 | | W | 1 | Damp and hazy. |
| | 2 | 0 | 58 | 59 | 30,09 | 58 | | S | 1 | Cloudy. |
| 27 | 8 | 0 | 55 | 57 | 30,14 | 53 | | S by E | 1 | Cloudy. |
| | 2 | 0 | 59 | 61 | 30,17 | 60 | | W | 1 | Cloudy. |
| 28 | 8 | 0 | 55 | 58 | 30,25 | 54 | | SSW | 1 | Cloudy. |
| | 2 | 0 | 60 | 58 | 30,25 | 61 | | SW | 1 | Cloudy and hazy. |
| 29 | 8 | 0 | 43 | 56 | 30,26 | 42 | | W | 1 | Thick fog. |
| | 2 | 0 | 60 | 60 | 30,20 | 61 | | E | 1 | Fine, rather hazy. |
| 30 | 8 | 0 | 45 | 56 | 30,11 | 42 | | E | 1 | Hazy. |
| | 2 | 0 | 54 | 59 | 30,04 | 55 | | SW | 1 | Fine. |
| 31 | 8 | 0 | 47 | 54 | 29,88 | 44 | | SE | 1 | Hazy. |
| | 2 | 0 | 57 | 58 | 29,91 | 59 | | W | 1 | Fine. |

Rain this Month 1,931 Inches.

## METEOROLOGICAL JOURNAL

### for November, 1821.

| 1821 | Time. H. | M. | Therm. without. ° | Therm. within. ° | Barom. Inches. | Six's Therm. | Winds. Points. | Str. | Weather. |
|---|---|---|---|---|---|---|---|---|---|
| Nov. 1 | 8 | 0 | 55 | 57 | 29,89 | 51 | S | 1 | Cloudy. |
| | 2 | 0 | 59 | 59 | 29,89 | 60 | SW | 1 | Cloudy. |
| 2 | 8 | 0 | 59 | 59 | 29,90 | 57 | W | 2 | Cloudy. |
| | 2 | 0 | 62 | 62 | 29,85 | 63 | W | 1 | Cloudy. |
| 3 | 8 | 0 | 55 | 60 | 29,80 | 54 | W | 1 | Cloudy. |
| | 2 | 0 | 57 | 56 | 29,77 | 63 | SW | 1 | Rain. |
| 4 | 8 | 0 | 44 | 55 | 29,21 | 42 | NW | 1,2 | Fine; stormy in the night |
| | 2 | 0 | 45 | 50 | 29,99 | 56 | W | 1 | Cloudy. |
| 5 | 8 | 0 | 35 | 42 | 30,03 | 34 | W | 1 | Fine. |
| | 2 | 0 | 44 | 48 | 30,12 | 45 | W | 1 | Cloudy and hazy. |
| 6 | 8 | 0 | 37 | 47 | 30,15 | 35 | W | 1 | Fine. |
| | 2 | 0 | 45 | 48 | 30,20 | 45 | W | 1 | Fine. |
| 7 | 8 | 0 | 42 | 48 | 30,13 | 37 | E | 1 | Fine. |
| | 2 | 0 | 48 | 49 | 30,08 | 49 | SE | 1 | Fine. |
| 8 | 8 | 0 | 42 | 49 | 30,05 | 42 | E | 1 | Fine, rather hazy. |
| | 2 | 0 | 48 | 55 | 30,05 | 49 | E | 1 | Cloudy. |
| 9 | 8 | 0 | 41 | 53 | 30,01 | 40 | E | 1 | Fine. |
| | 2 | 0 | 45 | 54 | 29,99 | 47 | E | 1 | Fine. |
| 10 | 8 | 0 | 44 | 53 | 29,97 | 41 | E | 1 | Foggy. |
| | 2 | 0 | 52 | 58 | 30,07 | 53 | E | 1 | Foggy. |
| 11 | 8 | 0 | 50 | 57 | 29,86 | 44 | SSE | 1 | Fine. |
| | 2 | 0 | 55 | 56 | 29,89 | 57 | SE | 1 | Rain. |
| 12 | 8 | 0 | 49 | 55 | 29,81 | 48 | W | 1 | Fine. |
| | 2 | 0 | 54 | 63 | 29,92 | 56 | E | 1 | Fine. |
| 13 | 8 | 0 | 46 | 57 | 29,99 | 44 | E | 1 | Foggy. |
| | 2 | 0 | 54 | 60 | 29,87 | 54 | E | 1 | Cloudy. |
| 14 | 8 | 0 | 53 | 59 | 29,71 | 46 | W | 1 | Hazy. |
| | 2 | 0 | 59 | 61 | 29,78 | 56 | W | 1 | Cloudy. |
| 15 | 8 | 0 | 53 | 60 | 29,74 | 50 | S | 1 | Fine. |
| | 2 | 0 | 60 | 63 | 29,60 | 61 | S | 1,2 | Cloudy. |
| 16 | 8 | 0 | 55 | 61 | 29,51 | 52 | SW | 2 | Cloudy. |
| | 2 | 0 | 54 | 62 | 29,41 | 60 | W | 1 | Cloudy. A violent storm of wind and rain from 10 A. M. to 3 P. M. |

Rain this Month 3,145 Inches.

## METEOROLOGICAL JOURNAL

### for November, 1821.

| 1821 | Time. H. | Time. M. | Therm. without. ° | Therm. within. ° | Barom. Inches. | Six's Therm. | | Winds. Points. | Winds. Scr. | Weather. |
|---|---|---|---|---|---|---|---|---|---|---|
| Nov. 17 | 8 | 0 | 52 | 63 | 29,53 | 49 | | W | 1 | Fine. |
| | 2 | 0 | 56 | 60 | 29,68 | 57 | | W | 1 | Cloudy. |
| 18 | 8 | 0 | 51 | 60 | 29,83 | 50 | | W | 1 | Cloudy. |
| | 2 | 0 | 59 | 59 | 30,02 | 59 | | W | 1 | Cloudy. |
| 19 | 8 | 0 | 50 | 58 | 29,99 | 47 | | S | 1 | Cloudy. |
| | 2 | 0 | 51 | 61 | 29,84 | 54 | | SW | 1 | Fine. |
| 20 | 8 | 0 | 46 | 58 | 30,01 | 44 | | W | 1,2 | Fine. |
| | 2 | 0 | 51 | 59 | 29,75 | 52 | | W | 1 | Cloudy. |
| 21 | 8 | 0 | 51 | 59 | 29,61 | 46 | | W | 1 | Cloudy and hazy. |
| | 2 | 0 | 48 | 61 | 29,75 | 53 | | NW | 1 | Fine. |
| 22 | 8 | 0 | 44 | 55 | 29,61 | 41 | | S | 1,2 | Rain. |
| | 2 | 0 | 57 | 62 | 29,47 | 58 | | W | 1,2 | Fine. |
| 23 | 8 | 0 | 52 | 59 | 29,73 | 45 | | W | 2 | Cloudy. |
| | 2 | 0 | 48 | 61 | 29,81 | 56 | | W | 1 | Fine. |
| 24 | 8 | 0 | 44 | 56 | 29,79 | 40 | | SW | 1 | Rain. |
| | 2 | 0 | 50 | 58 | 29,67 | 52 | | W | 1 | Cloudy. |
| 25 | 8 | 0 | 45 | 56 | 29,73 | 44 | | W | 1 | Fine. |
| | 2 | 0 | 48 | 56 | 29,77 | 51 | | W | 1 | Cloudy. |
| 26 | 8 | 0 | 45 | 57 | 29,36 | 54 | | S | 2 | Cloudy. |
| | 2 | 0 | 54 | 60 | 29,22 | 56 | | W | 3 | Stormy. |
| 27 | 8 | 0 | 45 | 56 | 29,43 | 45 | | W | 1 | Cloudy. |
| | 2 | 0 | 46 | 57 | 29,60 | 50 | | W | 1 | Fine. |
| 28 | 8 | 0 | 40 | 53 | 29,81 | 36 | | SW | 1 | Fine. |
| | 2 | 0 | 50 | 57 | 29,63 | 55 | | W | 1 | Cloudy. |
| 29 | 8 | 0 | 53 | 57 | 29,57 | 41 | | WSW | 3 | Rain. |
| | 2 | 0 | 51 | 62 | 29,74 | 55 | | W | 1 | Fine. |
| 30 | 8 | 0 | 43 | 55 | 29,78 | 43 | | W | 1 | Fine. |
| | 2 | 0 | 49 | 58 | 29,91 | 52 | | SW | 1 | Cloudy and hazy. |

Rain this Month 3,445 Inches.

## METEOROLOGICAL JOURNAL

### for December, 1821.

| 1821 | Time. H. | Time. M. | Therm. without. ° | Therm. within. ° | Barom. Inches. | Six's Therm. | | Winds. Points. | Winds. Str. | Weather. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | [in the night. |
| Dec. 1 | 8 | 0 | 44 | 55 | 29,56 | 43 | | E | 2 | Fine, a violent gale of wind |
| | 2 | 0 | 46 | 58 | 29,64 | 55 | | W | 1 | Fine. [ning in the night. |
| 2 | 8 | 0 | 44 | 53 | 29,81 | 41 | | W | 1 | Cloudy, wind and light- |
| | 2 | 0 | 48 | 56 | 29,87 | 49 | | W | 1 | Fine. |
| 3 | 8 | 0 | 50 | 53 | 29,75 | 40 | | S | 2 | Cloudy. |
| | 2 | 0 | 54 | 58 | 29,59 | 58 | | NW | 1,2 | Rain. |
| 4 | 8 | 0 | 39 | 52 | 29,86 | 37 | | W | 1 | Fine. |
| | 2 | 0 | 56 | 57 | 29,87 | 57 | | W | 1 | Cloudy. |
| 5 | 8 | 0 | 48 | 55 | 29,74 | 39 | | W | 2 | Rain. [ning at 3 P. M. |
| | 2 | 0 | 58 | 60 | 29,80 | 48 | | W | 1,2 | Rain, thunder and light- |
| 6 | 8 | 0 | 39 | 53 | 30,12 | 38 | | W | 1 | Hazy. |
| | 2 | 0 | 43 | 56 | 30,19 | 48 | | W | 1 | Fine. |
| 7 | 8 | 0 | 40 | 53 | 30,10 | 38 | | SE | 1 | Cloudy. |
| | 2 | 0 | 45 | 56 | 29,90 | 45 | | SE | 1 | Cloudy. |
| 8 | 8 | 0 | 48 | 55 | 29,96 | 43 | | W | 1 | Cloudy. |
| | 2 | 0 | 51 | 57 | 30,03 | 52 | | W | 1 | Cloudy. |
| 9 | 8 | 0 | 48 | 56 | 30,08 | 44 | | SW | 1 | Cloudy. |
| | 2 | 0 | 52 | 56 | 30,08 | 54 | | W | 1 | Rain. |
| 10 | 8 | 0 | 48 | 56 | 30,05 | 44 | | S | 2 | Cloudy. |
| | 2 | 0 | 53 | 59 | 29,98 | 54 | | S | 2 | Fine. |
| 11 | 8 | 0 | 43 | 55 | 30,17 | 43 | | W | 1 | Foggy. |
| | 2 | 0 | 46 | 59 | 30,26 | 54 | | N | 1 | Fine. |
| 12 | 8 | 0 | 42 | 53 | 30,28 | 37 | | E | 1 | Fine. |
| | 2 | 0 | 48 | 56 | 30,21 | 48 | | SSE | 1 | Cloudy. |
| 13 | 8 | 0 | 47 | 54 | 29,95 | 45 | | S by E | 1 | Cloudy. |
| | 2 | 0 | 52 | 59 | 29,92 | 53 | | S by E | 1 | Fine. |
| 14 | 8 | 0 | 43 | 56 | 30,00 | 42 | | S | 1 | Fine. |
| | 2 | 0 | 51 | 56 | 29,98 | 54 | | SW | 1 | Rain. |
| 15 | 8 | 0 | 49 | 56 | 29,96 | 43 | | S | 1 | Fine. |
| | 2 | 0 | 51 | 60 | 29,96 | 53 | | SSW | 1 | Fine. |
| 16 | 8 | 0 | 50 | 55 | 29,80 | 49 | | S | 1 | Fine. |
| | | | 53 | 57 | 29,73 | 54 | | S | 1 | Cloudy. |

Rain this Month 3,916 Inches.

## METEOROLOGICAL JOURNAL
### for December, 1821.

| 1821 | Time. H. | M. | Therm. without. ° | Therm. within. ° | Barom. Inches. | Six's Therm. | | Winds. Points. | Str. | Weather. |
|---|---|---|---|---|---|---|---|---|---|---|
| Dec. 17 | 8 | 0 | 50 | 53 | 29,51 | 49 | | SW | 2,3 | Rain. |
| | 2 | 0 | 52 | 55 | 29,49 | 53 | | SW | 1 | Cloudy. [at 3 A. M. |
| 18 | 8 | 0 | 45 | 55 | 28,98 | 43 | | W | 1 | Fine, a most violent gale |
| | 2 | 0 | 50 | 58 | 29,13 | 53 | | W | 2 | Rain and hail. |
| 19 | 8 | 0 | 45 | 54 | 29,03 | 44 | | SW | 1 | Fine. |
| | 2 | 0 | 49 | 57 | 29,12 | 50 | | NW | 1 | Fine. |
| 20 | 8 | 0 | 42 | 53 | 29,31 | 40 | | W | 1 | Foggy. |
| | 2 | 0 | 46 | 57 | 29,37 | 51 | | W | 1 | Fine. |
| 21 | 8 | 0 | 47 | 54 | 28,80 | 40 | | NW | 2 | Cloudy. |
| | 2 | 0 | 49 | 52 | 29,12 | 50 | | W | 2 | Fine. |
| 22 | 8 | 0 | 41 | 53 | 29,41 | 41 | | SW | 1 | Fine. |
| | 2 | 0 | 49 | 57 | 29,48 | 50 | | W | 1 | Cloudy. |
| 23 | 8 | 0 | 42 | 52 | 28,97 | 41 | | W | 2 | Fine. |
| | 2 | 0 | 47 | 52 | 29,15 | 52 | | W | 1 | Rain. |
| 24 | 8 | 0 | 43 | 51 | 28,92 | 41 | | S | 2 | Rain. |
| | 2 | 0 | 47 | 54 | 28,75 | 48 | | E | 1 | Rain. |
| 25 | 8 | 0 | 40 | 52 | 28,18 | 40 | | S | 1 | Cloudy. |
| | 2 | 0 | 42 | 53 | 28,46 | 48 | | W | 1 | Fine. |
| 26 | 8 | 0 | 37 | 49 | 28,51 | 36 | | E | 1 | Hazy. |
| | 2 | 0 | 42 | 53 | 28,48 | 45 | | E | 1 | Cloudy. |
| 27 | 8 | 0 | 39 | 48 | 28,91 | 35 | | S | 1 | Fine. |
| | 2 | 0 | 45 | 51 | 28,98 | 46 | | S | 1,2 | Fine. |
| 28 | 8 | 0 | 40 | 49 | 29,85 | 39 | | S | 1,2 | Cloudy. [wind and rain. |
| | 2 | 0 | 44 | 49 | 28,45 | 46 | | E | 3 | Rain, a violent squall of |
| 29 | 8 | 0 | 44 | 50 | 28,30 | 37 | | E | 1 | Thick fog. |
| | 2 | 0 | 48 | 53 | 28,56 | 48 | | W | 1 | Cloudy. |
| 30 | 8 | 0 | 42 | 50 | 29,01 | 42 | | W | 1 | Cloudy. |
| | 2 | 0 | 44 | 50 | 29,15 | 47 | | NW | 1 | Rain. |
| 31 | 8 | 0 | 37 | 48 | 29,84 | 37 | | W | 1 | Fine. |
| | 2 | 0 | 44 | 53 | 29,96 | 45 | | W | 1 | Fine. |

Rain this Month 3,936 Inches.

| 1821. | Thermometer without. | | | Thermometer within. | | | Barometer.* | | | Six's Thermometer. | | | Rain.† |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Greatest height. | Least height. | Mean height. | Greatest height. | Least height. | Mean height. | Greatest height. | Least height. | Mean height. | Greatest height. | Least height. | Mean height. | |
| | Deg. | Deg. | Deg. | Deg. | Deg. | Deg. | Inches. | Inches. | Inches. | Deg. | Deg. | Deg. | Inches. |
| January | 51 | 25 | 39,5 | 58 | 38 | 49,0 | 30,76 | 28,98 | 30,01 | 52 | 25 | 39,7 | 1,854 |
| February | 59 | 25 | 38,0 | 59 | 42 | 50,3 | 30,77 | 29,21 | 30,23 | 61 | 25 | 38,4 | 0,278 |
| March | 57 | 34 | 44,7 | 69 | 48 | 56,4 | 30,38 | 29,06 | 29,63 | 59 | 31 | 45,2 | 1,917 |
| April | 71 | 37 | 53,5 | 69 | 51 | 58,6 | 30,12 | 29,25 | 29,65 | 72 | 36 | 53,1 | 1,137 |
| May | 66 | 42 | 53,3 | 65 | 52 | 57,8 | 30,25 | 29,17 | 29,86 | 70 | 37 | 52,7 | 1,093 |
| June | 72 | 47 | 57,7 | 67 | 52 | 59,4 | 30,32 | 29,57 | 30,03 | 73 | 43 | 57,0 | 1,833 |
| July | 72 | 51 | 60,9 | 71 | 57 | 62,4 | 30,30 | 29,56 | 29,91 | 74 | 46 | 60,6 | 2,236 |
| August | 76 | 56 | 65,3 | 79 | 61 | 66,6 | 30,19 | 29,47 | 29,92 | 77 | 50 | 64,7 | 2,097 |
| September | 71 | 49 | 62,4 | 71 | 57 | 64,0 | 30,20 | 29,49 | 29,85 | 75 | 46 | 62,0 | 1,810 |
| October | 66 | 43 | 53,3 | 67 | 53 | 57,4 | 30,33 | 29,11 | 29,87 | 68 | 41 | 52,7 | 1,931 |
| November | 62 | 35 | 49,7 | 63 | 42 | 56,8 | 30,20 | 29,21 | 29,80 | 63 | 34 | 49,6 | 3,445 |
| December | 58 | 37 | 46,1 | 60 | 49 | 54,3 | 30,28 | 28,18 | 29,51 | 58 | 36 | 45,8 | 3,936 |
| Whole year | | | 52,0 | | | 57,8 | | | 29,86 | | | 51,8 | 23,567 |

* The quicksilver in the bason of the barometer is 81 feet above the level of low water spring tides at Somerset-house.

† The Society's Rain Gage is 114 feet above the same level, and 75,6 inches above the surrounding ground.